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BUSINESS CYCLE AND BANK CAPITAL: MONETARY POLICY TRANSMISSION UNDER THE BASEL ACCORDS

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Business Cycle and Bank Capital: Monetary Policy Transmission under the Basel Accords

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Abstract

This paper improves the analysis of the role of financial frictions in the transmission of monetary policy and in business cycle fluctuations, by focusing on an additional channel working through bank capital.

Detailing a dynamic general equilibrium model, in which households require a (counter-cyclical) liquidity premium to hold bank capital, we find that, together with the financial accelerator, the introduction of regulatory bank capital significantly amplifies monetary shocks through a liquidity premium effect on the external finance premium faced by firms. This amplification effect is larger under Basel II than under Basel I regulatory rules.

Indeed, introducing bank capital enhances the role of financial frictions in the propagation of shocks, in line with arguments in related literature.

Keywords: Bank capital channel; Bank capital requirements; Financial accelerator; Liquidity premium; Monetary transmission mechanism; Basel Accords

JEL Classification Codes: E44, E32, E52, G28

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1 Introduction

The precise mechanisms through which monetary policy affects real activity are not completely clarified. Some recent literature explores the possible explanation of monetary policy effects through financial imperfections. Our work fits in this line of research by centering its attention on how microeconomic structures, such as the bank funding structure and the relationship between the bank and the borrower, interact with macroeconomic business conditions. In particular, we contribute to clarify the role of bank capital and its regulatory environment in lending conditions and, consequently, in the transmission of monetary policy and in business cycle fluctuations.

An additional motivation lies in current changes in the regulatory environment. In fact, the study of bank capital - business cycle interactions is quite up to date, both at the academic and institutional level, due to the implications of the changeover from Basel I to Basel II bank capital requirements rules, whose implementation have begun in January 2007.¹

The existence of empirical evidence that the bank funding structure, or, more specifically, the bank capital, affects its supply of loans and, consequently, real activity, has motivated our modelization of the banking relationships in the context of a dynamic general equilibrium model.

First, one strand of this empirical literature indicates that lending growth after a monetary policy shock depends on the level of bank capital: using U.S. data from 1980 to 1995, Kishan and Opiela (2000) predict that poorly capitalized banks experience more significant declines in their lending, following monetary contractions. Their results are in line with Van den Heuvel (2002b)'s, who, also using U.S. data, from 1969 until 1995, shows that the real effects of monetary policy are stronger when banks have low capital relative to the existing bank capital requirements: when a U.S. state's banking sector starts out with a low capital-asset ratio, subsequent output growth in that state is more sensitive to changes in the Federal funds rate and other indicators of monetary policy. After the implementation of Basel I and FDICIA (the Federal Deposit Insurance Corporation Improvement Act of 1991) in the U.S., the loan response by banks to monetary policy appears to be asymmetric, according to Kishan and Opiela (2006): a contractionary monetary policy decreases the loans of the small low-capital banks relative to high-capital banks, and an expansionary monetary policy is not able to increase the loan growth of the low-capital banks relative to the high-capital banks. Also in this line of research, Hubbard *et al.* (2002) find that, even after controlling for information costs and borrower risk, the cost of borrowing from low-capital banks is higher than the cost of borrowing from well-capitalized banks; that is, capital

¹The relevant regulatory framework is determined by Basel I and Basel II, the Basel Accords of 1988 and 2004, respectively, detailed in Basle Committee on Banking Supervision (1988, 2004).

positions of individual banks affect the interest rate at which their clients borrow.

Second, as mentioned by Van den Heuvel (2002a), the importance of bank capital on lending has increased since the implementation of Basel I, which, by imposing risk-based capital requirements, limits the ability of banks with a shortage of capital to supply loans. There is a considerable number of papers that test the hypothesis of a "credit crunch" - a significant leftward shift in the supply curve for bank loans - that may have occurred in the U.S. during the early 90s, simultaneously with the implementation of the new banking system regulation established by the Basel Accord. The idea behind those studies is that, given the common perception that bank capital is more costly than alternative funding sources (such as deposits), regulatory capital requirements can have real effects: in order to satisfy those requirements, banks may choose to reduce loans and, in such an event, some otherwise worthy borrowers cannot obtain them. The allocation of credit away from loans can, in turn, cause a significant reduction in macroeconomic activity, given that many borrowers cannot easily obtain substitute sources of funding in public markets. On this credit crunch literature, see, for instance, Bernanke and Lown (1991), Peek and Rosengren (1995, 2000), and Sharpe (1995) for a review.

Some studies in this literature are, however, quite skeptical about the role of the credit crunch in worsening the 1990 recession in the U.S. (*e.g.*, Bernanke and Lown, 1991): they suggest that demand factors, including the weakened state of borrowers' balance sheet, were instead the major cause of the lending slowdown. In contrast, Peek and Rosengren (2000), for instance, focusing on the strong downward pressure on capital positions of Japanese banks with branches in the U.S., identified an independent loan supply disruption and argued that this shock had substantial effects on real economic activity in the U.S..

This controversy illustrates one of the major difficulties of this type of analysis: it is hard to distinguish between movements in loan demand and movements in loan supply, especially because, as mentioned by Van den Heuvel (2002b), there is no interest rate summarizing the effective cost of financing, since this cost depends not only on the contractual interest rate, but also on collateral requirements, the extent of rationing, and other contractual features. Therefore, although there is some evidence that bank capital affects bank lending and, consequently, real activity, these studies are not completely successful in distinguishing shifts in loan demand from shifts in loan supply, leaving the question of the relative importance of different effects unanswered.

Our model contributes to evaluate the relative importance of these loan supply and demand effects, by bringing together, in a dynamic general equilibrium model, the borrowers' balance sheet channel developed by Bernanke *et al.* (1999), with an additional channel working through bank capital, which also amplifies the real effects of exogenous nominal and real shocks. That is, taking

the Bernanke *et al.*'s dynamic general equilibrium model as a starting point, we add banks that, due to the imposition of regulatory capital requirements, face financial frictions when raising funds.

This debate on the role of bank capital in business cycle fluctuations is quite relevant in the context of current implementation of Basel II. One of the central changes proposed by the new Basel Accord is the increased sensitivity of a bank's capital requirement to the risk of its assets: the amount of capital that a bank must hold is determined, not only by the institutional nature of its borrowers (as in Basel I), but also by the riskiness of each particular borrower. Specifically, an increase in the credit risk of a given asset should lead to an increase in the amount of capital that a bank must hold against it. This has raised some concerns about the potential procyclical effects of Basel II: during a recession, for instance, if non-defaulted loans are considered riskier, banks will be required to hold more capital, or further reduce lending, thus exacerbating the economic downturn. In fact, the final version of Basel II recognized some specific measures to address these potential procyclical effects, *e.g.*, banks adopting Basel II rules are required to follow a through-the-cycle approach to compute the default probability over the life of the loan, rating borrowers according to their ability to withstand a recession.

Theoretically, our model has been decisively motivated by Bernanke *et al.* (1999)'s suggestion, in their concluding remarks, to introduce the specific role of banks in cyclical fluctuations. Although excluding some bank activities, for simplicity, our model explicitly assumes the role of banks in financing two entities in financial deficit (the public sector and nonfinancial firms) using the funds of households (the entity in financial surplus). We assume that banks are constrained by a risk-based capital ratio requirement according to which the ratio of bank capital to nonfinancial loans cannot fall below a regulatory minimum exogenously set. Banks are, thus, limited in their lending to nonfinancial firms by the amount of bank capital that households are willing to hold. Taking into account that bank capital is more expensive to raise than deposits, due to households' preferences for liquidity, and that this difference tends to widen (narrow) during a recession (expansion), we explore the additional channel through which the effects of exogenous shocks on real activity are amplified - the bank capital channel. The model is then extended in order to evaluate the impact of the bank capital channel under Basel I *versus* Basel II, thus aiming to shed additional light on the debate about the potential procyclical effects of Basel II.

Related theoretical literature

The theoretical literature distinguishes three channels of propagation of the effects of monetary policy, through mechanisms related to financial imperfections: (*i*) the bank lending channel, based

on reserve requirements by monetary authorities; *(ii)* the borrowers' balance sheet channel, focusing on borrowers' financial position and, more recently, *(iii)* the bank capital channel.

Our model abstracts, for simplicity, from the bank lending channel (as Bernanke *et al.*, 1999) to focus on the other two - it combines loan demand shifts arising from the borrowers' balance sheet channel with loan supply shifts related to the bank capital channel. Since the borrowers' balance sheet channel has been more extensively studied,² we focus this brief review on the bank-capital-channel theoretical models.

These models can be divided into two groups: one that focus on bank *market* capital requirements and another based on bank *regulatory* capital requirements. Chen (2001) and Meh and Moran (2004) belong to the first group and are built upon Holmstrom and Tirole (1997) formulation that features two sources of moral hazard (between banks and borrowers and between banks and depositors). In particular, according to Meh and Moran's model, a contractionary monetary policy raises the opportunity cost of the external funds that banks use to finance investment projects and leads the market to require banks and firms to finance a larger share of investment projects with their own net worth. Since banks and firms' net worth are largely predetermined, bank lending must decrease to satisfy those market requirements, thereby leading to a decrease in investment. This mechanism implies a decrease in banks and firms' earnings and, consequently, a decrease in banks and firms' net worth in the future. Therefore, there is a propagation of the shock over time after the initial impulse to the interest rate has dissipated. Sunirand (2003) also focuses on market capital requirements, by extending the financial accelerator model of Bernanke *et al.* (1999) to consider a two-sided costly state verification framework, thus motivating an endogenous role for firms' and banks' capital in the model: banks act as delegated monitors on firms' investment projects, as in Bernanke *et al.*, and depositors perform the role of 'monitoring the monitor'. By embedding the informational asymmetry between households and banks into the financial accelerator model, the effects of a negative monetary shock on aggregate output and investment are amplified.

Among the studies in the second group, *i.e.*, assuming *regulatory* bank capital requirements, are Blum and Hellwig (1995), Van den Heuvel (2002a, 2005), Berka and Zimmermann (2005), Bolton and Freixas (2006) and Repullo and Suarez (2007).

According to Van den Heuvel (2002a)'s model, an increase in funds rate (due to a contractionary monetary policy) and, consequently, an increase in bank's cost of funding, leads to a decrease in bank's profits, given the maturity mismatch on the bank's balance sheet. This, in turn, weakens the bank's future capital position, increasing the likelihood that its lending will be constrained by

²See Bernanke (1993) and Bernanke and Gertler (1995) for a review.

an inadequate level of capital. Therefore, new lending overreacts to the monetary policy shock, when compared to a situation of unconstrained banks. Van den Heuvel refers to this channel by which monetary policy influences the supply of bank loans through its impact on bank capital as the bank capital channel. The strength of this channel depends on the capital adequacy of the banking sector and the distribution of capital across banks. In particular, lending by banks with low capital is delayed and then amplified in reaction to interest rate shocks, relative to well capitalized banks.

Berka and Zimmermann (2005) and Bolton and Freixas (2006) also assume regulatory capital requirements, but, in contrast with Van den Heuvel (2002a), consider the possibility of bank capital issuance.

Capital issuance may involve costs, as in Bolton and Freixas (2006), which consider a cost of outside capital for banks by assuming information dilution costs in issuing bank capital: outside equity investors, having less information about the profitability of bank loans, will tend to misprice the capital issues of the most profitable banks. In this context, the presence of regulatory (and binding) capital requirements may magnify the effects of a contractionary monetary policy, since this policy may trigger a decrease (or prevent an increase) in bank capital: a contractionary monetary policy may render bank loans insufficiently lucrative when information dilution costs in issuing bank capital are taken into account.

According to Berka and Zimmermann (2005), when an initial negative shock hits the economy, bank capital becomes more risky and households channel their savings away from capital and into deposits. The banks are then squeezed by the binding regulatory capital requirements and have to decrease their loan supply and invest more into government bonds. Without capital requirements, banks could supply more loans, in principle, by charging even higher loan rates, and entrepreneurs would still be ready to pay these rates.

In a slightly different perspective, Van den Heuvel (2005) quantifies the welfare costs of bank capital requirements by embedding the role of liquidity creation by banks in a general equilibrium model, with no aggregate uncertainty. The households' preferences for liquidity play here a major role: equilibrium asset returns reveal the strength of these preferences and allow the quantification of the ("neither trivial nor gigantic", according to the author) welfare costs of bank capital requirements. Regulators, thus, face a trade-off between keeping the effective capital requirement ratio as low as possible while keeping the probability of bank failure acceptably low.

Concerning, in particular, Basel II capital requirements, the still preliminary work of Repullo and Suarez (2007) considers the possibility that banks optimally choose to keep capital buffers, thus, counteracting the potential procyclicality of the new Basel Accord. The partial equilibrium

model developed by these authors predicts, however, that these capital buffers are insufficient to neutralize this procyclicality: during a recession banks will significantly decrease the supply of credit causing a credit crunch that would not occur under Basel I.

Our model relates to this literature by accounting for the interactions between bank capital and macroeconomic conditions. We assume that banks issue capital to satisfy regulatory capital requirements (as Berka and Zimmermann, 2005, and Bolton and Freixas, 2006) and that households' preferences for liquidity matter for banks' funding structure. By doing this, our model yields a liquidity premium effect on the external finance premium faced by firms, a mechanism through which bank capital affects the transmission of monetary policy to the real economy.³ According to our results, this additional mechanism is responsible for a significant amplification of the immediate effects of a monetary policy shock, the more significant the closer the regulatory rules are to Basel II, rather than to Basel I.

The paper is organized as follows. After this introduction, section 2 develops and calibrates a dynamic general equilibrium model, with particular attention to the banking relationships with entrepreneurs and households. Section 3 simulates a monetary policy shock under several variants of the model, in order to analyze the role of bank capital in the monetary policy transmission mechanism and the relative importance of demand and supply-of-loans effects. Section 4 extends the baseline model to evaluate and compare the magnitude of the demand and supply-of-loans effects under Basel I and Basel II. Section 5 offers current conclusions of this ongoing research.

2 A Model with Bank Capital

In order to analyze the role of bank capital in the transmission mechanism of monetary policy, and, thus, in business cycle fluctuations, we develop a dynamic general equilibrium model, assuming five types of agents in the economy:

- Households, who work, consume and allocate their savings to bank deposits and bank capital;
- Entrepreneurs, who need external (bank) finance to buy capital, which is used in combination with hired labor to produce wholesale output;
- Banks, which, using the funds of households, finance and monitor (*ex post*) the entrepreneurs;

³Our meaning of the bank capital channel, thus, differs from Van den Heuvel (2002a)'s, in which households and liquidity preferences and, thus, the liquidity premium effect, are absent.

- Retailers, added in order to incorporate inertia in price setting;
- Government, which conducts both monetary and fiscal policy and regulates banks.

2.1 Entrepreneurs

The analysis of entrepreneurs' behavior follows closely the model of Bernanke, Gertler and Gilchrist (1999), BGG hereafter.

In each period each entrepreneur buys the entire capital stock for his firm in order to, in combination with labor, produce output in the next period. More specifically, at time t , entrepreneur j purchases homogeneous capital for use at $t + 1$, K_{t+1}^j . The return to capital is sensitive to both aggregate and idiosyncratic risk. The *ex post* gross return on capital for firm j is $\omega_{t+1}^j R_{t+1}^K$, where ω_{t+1}^j is an idiosyncratic disturbance to firms j 's return and R_{t+1}^K is the *ex post* aggregate return to capital. The random variable ω^j is independently and identically distributed (i.i.d.) across time and across firms, with a continuous and once-differentiable cumulative distribution function (c.d.f.), $F(\omega)$, over a non-negative support, and $E(\omega^j) = 1$.

At the end of period t , entrepreneur j has available net worth N_{t+1}^j which he uses to finance the acquisition of K_{t+1}^j . To finance the difference between his capital expenditures and his net worth, he must borrow an amount $L_{t+1}^j = Q_t K_{t+1}^j - N_{t+1}^j$, where Q_t represents the price paid per unit of capital at time t . Each entrepreneur then borrows from a financial intermediary (bank) which imposes a required return on lending between t and $t + 1$, R_{t+1}^F . This relationship embodies an asymmetric information problem between each entrepreneur and the bank: only the entrepreneur observes costlessly the return of his project. The financial contract established between these two agents is, then, designed to minimize the expected agency costs. That is, as in BGG, we assume a costly state verification (CSV) problem, in which the bank must pay a monitoring cost in order to observe an individual borrower's realized return. This monitoring cost is assumed to equal a proportion μ of the realized gross payoff of the firm's capital:

$$\mu \omega_{t+1}^j R_{t+1}^K Q_t K_{t+1}^j,$$

where $0 < \mu < 1$. The idiosyncratic disturbance ω_{t+1}^j is unknown to both the entrepreneur and the bank prior to the investment decision. That is, $Q_t K_{t+1}^j$ and L_{t+1}^j are chosen prior to the realization of the idiosyncratic shock. After the investment decision is made, the bank can only observe ω_{t+1}^j by paying the monitoring cost.

Given $Q_t K_{t+1}^j$, L_{t+1}^j and R_{t+1}^K , the optimal contract is characterized by a gross non-default loan rate, Z_{t+1}^j , and a cutoff value $\bar{\omega}_{t+1}^j$, such that, if $\omega_{t+1}^j \geq \bar{\omega}_{t+1}^j$, the borrower pays the lender

the amount $\bar{\omega}_{t+1}^j R_{t+1}^K Q_t K_{t+1}^j$ and keeps the remaining $(\omega_{t+1}^j - \bar{\omega}_{t+1}^j) R_{t+1}^K Q_t K_{t+1}^j$. That is, $\bar{\omega}_{t+1}^j$ is defined by

$$\bar{\omega}_{t+1}^j R_{t+1}^K Q_t K_{t+1}^j = Z_{t+1}^j L_{t+1}^j. \quad (1)$$

If $\omega_{t+1}^j < \bar{\omega}_{t+1}^j$, the borrower receives nothing, while the bank monitors the borrower and receives $(1 - \mu)\omega_{t+1}^j R_{t+1}^K Q_t K_{t+1}^j$.

In equilibrium, the contract guarantees the lender an expected gross return on the loan equal to the required return R_{t+1}^F (taken as given in the contracting problem). That is,

$$\begin{aligned} [1 - F(\bar{\omega}_{t+1}^j)] Z_{t+1}^j L_{t+1}^j + (1 - \mu) \int_0^{\bar{\omega}_{t+1}^j} \omega_{t+1}^j R_{t+1}^K Q_t K_{t+1}^j f(\omega) d\omega = \\ = R_{t+1}^F (Q_t K_{t+1}^j - N_{t+1}^j), \end{aligned} \quad (2)$$

where $f(\omega)$ is the probability density function (p.d.f.) of ω .

Combining equation (1) with equation (2) yields the following expression:

$$\begin{aligned} \left\{ [1 - F(\bar{\omega}_{t+1}^j)] \bar{\omega}_{t+1}^j + (1 - \mu) \int_0^{\bar{\omega}_{t+1}^j} \omega_{t+1}^j f(\omega) d\omega \right\} R_{t+1}^K Q_t K_{t+1}^j = \\ = R_{t+1}^F (Q_t K_{t+1}^j - N_{t+1}^j). \end{aligned} \quad (3)$$

As shown by BGG, the bank's expected return reaches a maximum at an unique interior value of $\bar{\omega}_{t+1}^j$, $\bar{\omega}_{t+1}^{j*}$, and equilibrium is characterized by $\bar{\omega}_{t+1}^j$ always below $\bar{\omega}_{t+1}^{j*}$. Therefore, the hypothesis of an equilibrium with credit rationing is ruled out and the bank's expected return is always increasing in $\bar{\omega}_{t+1}^j$.

With aggregate uncertainty present, $\bar{\omega}_{t+1}^j$ depends on the *ex post* realization of R_{t+1}^K : conditional on the *ex post* realization of R_{t+1}^K , the borrower offers a state-contingent non-default payment that guarantees the lender a return equal in expected value to the required return R_{t+1}^F . Thus, condition (3) implies a set of restrictions, one for each realization of R_{t+1}^K .

The optimal contracting problem determines the division, between the borrower j and the bank, of the expected gross payoff to the firm's capital, $E_t(R_{t+1}^K) Q_t K_{t+1}^j$, where E_t denotes the expectation operator conditional on the information available at time t . The optimal contract results from the maximization of borrower's payoff, with respect to K_{t+1}^j and $\bar{\omega}_{t+1}^j$, subject to the

set of state-contingent constraints implied by (3).

Let l_{t+1} represent $\frac{E_t(R_{t+1}^K)}{R_{t+1}^F}$, the expected discounted return to capital. Given $l_{t+1} > 1$, the first order conditions of the contracting problem yield the following relationship between $\frac{Q_t K_{t+1}^j}{N_{t+1}^j}$ and the expected discounted return to capital (see BGG for details):

$$\frac{Q_t K_{t+1}^j}{N_{t+1}^j} = \varphi \left(\frac{E_t(R_{t+1}^K)}{R_{t+1}^F} \right),$$

where $\varphi'(\cdot) > 0$ and $\varphi(1) = 1$. Therefore, each borrower's capital expenditures are proportional to his net worth, with a proportionality factor that is increasing in the expected discounted return to capital. As mentioned by BGG, everything else equal, a rise in the expected discounted return to capital reduces the expected default probability. As a consequence, the entrepreneur can borrow more and expand the size of his firm. Since the expected default costs also increase as the ratio of borrowing to net worth increases, the entrepreneur cannot expand the size of his firm indefinitely.

Aggregating the preceding equation over firms we obtain⁴

$$\frac{Q_t K_{t+1}}{N_{t+1}} = \varphi \left(\frac{E_t(R_{t+1}^K)}{R_{t+1}^F} \right), \quad (4)$$

where K_{t+1} denotes the aggregate amount of capital purchased by all entrepreneurs at time t , and N_{t+1} the aggregate net worth of those agents.

Equivalently, equation (4) can be expressed as

$$\frac{E_t(R_{t+1}^K)}{R_{t+1}^F} = l \left(\frac{Q_t K_{t+1}}{N_{t+1}} \right), \quad (5)$$

where $l(\cdot)$ is increasing in $\frac{Q_t K_{t+1}}{N_{t+1}}$ for $N_{t+1} < Q_t K_{t+1}$. Thus, in equilibrium, the expected discounted return to capital, $\frac{E_t(R_{t+1}^K)}{R_{t+1}^F}$, depends negatively on the share of the firms' capital expenditures that is financed by the entrepreneurs' net worth. As argued by Walentin (2003), $l \left(\frac{Q_t K_{t+1}}{N_{t+1}} \right) R_{t+1}^F$ should be interpreted as the return on capital required by banks, in order to grant loans to the firms. Therefore, in an environment where entrepreneurs must borrow, under imperfect information, to buy capital, the expected discounted return to capital, $\frac{E_t(R_{t+1}^K)}{R_{t+1}^F}$, may be interpreted as an opportunity cost of being an entrepreneur, or, as in BGG's acceptance, as the *external finance*

⁴As mentioned by BGG, the assumption of constant returns to scale generates a proportional relationship between net worth and the capital demand at the firm level, with a factor of proportionality independent of firm's specific factors. This facilitates aggregation.

premium faced by entrepreneurs.

Entrepreneurial Net Worth The net worth of entrepreneurs combines profits accumulated from previous capital investment with income from supplying labor. As a technical matter, it is necessary to start entrepreneurs off with some net worth in order to allow them to begin operations: as in BGG, we assume that, in addition to operating firms, entrepreneurs supplement their income by working. It is also assumed that the fraction of agents who are entrepreneurs remains constant.

Let V_t be the entrepreneurs' total equity (*i.e.*, wealth accumulated by entrepreneurs from operating firms). Then, normalizing the total entrepreneurial labor to one,

$$N_{t+1} = \gamma V_t + W_t^e, \quad (6)$$

where W_t^e is the entrepreneurial wage and γ is the probability that a entrepreneur survives to the next period. To avoid the possibility that entrepreneurs accumulate enough net worth to be fully self financed, it is assumed that those agents have finite horizons. The fraction of agents who are entrepreneurs is held constant by the birth of a new entrepreneur for each dying one.

Note that V_t can be expressed, in equilibrium, as

$$V_t = R_t^K Q_{t-1} K_t - R_t^F (Q_{t-1} K_t - N_t) - \mu \Theta(\bar{\omega}_t) R_t^K Q_{t-1} K_t, \quad (7)$$

where $\mu \Theta(\bar{\omega}_t) R_t^K Q_{t-1} K_t$ are the aggregate default monitoring costs with $\Theta(\bar{\omega}_t) \equiv \int_0^{\bar{\omega}_t} \omega_t^j f(\omega) d\omega$. Thus, combining equations (6) and (7), it is straightforward to conclude that N_{t+1} reflects the equity stake that entrepreneurs have in their firms, which in turn depends on firms' earnings net of interest payments to financial intermediaries.

Entrepreneurs who "die" in t are not allowed to buy capital and simply consume their residual equity $(1 - \gamma)V_t$. That is,

$$C_t^e = (1 - \gamma)V_t, \quad (8)$$

where C_t^e represents the total consumption of entrepreneurs who leave the market.

2.2 Banks

Financial intermediation, consisting of collecting funds from households and granting loans to entrepreneurs, is assured by banks. In this respect we depart from BGG by properly defining the financial intermediaries as banks and, consequently, specifying their behavior.

Banks are not subject to reserve requirements (for simplicity), but are legally subject to a risk-based regulatory capital requirement. In particular, banks must hold an amount of equity that covers at least a given percentage of loans, exogenously set by the regulator. We assume that only banks issue equity (as in Bolton and Freixas, 2006, for instance), on terms that depend on demand, *i.e.*, on households' willingness to hold capital in addition to deposits. Banks' assets comprise, not only loans to firms, but also government bonds, which have zero weight in the risk-based capital requirement since they bear no risk.

Another specificity of banks is the technology needed to monitor entrepreneurs. Since households do not have access to this technology, they delegate monitoring to banks, which undertake the costly state verification defined above. In this framework, each bank does not have any bargaining power in the relationship with the borrower firm - the contract specifies the maximization of borrower's payoff subject to the constraint that the expected return to the bank covers only its opportunity cost of funds. In other words, we are assuming a competitive banking system (as in Berka and Zimmermann, 2005, for instance) with unrestricted entry, where each bank earns zero profits, in equilibrium.

In this context, we will now analyze the behavior of a representative bank which maximizes its expected profits, acting as a price (interest rate) taker in a competitive market. Its choice variables are loans, riskless government bonds, deposits and capital. Beside the capital requirements, we will also assume that the bank must buy deposit insurance. More specifically, the bank is subject to an insurance rate on deposits which depends negatively on the level of bank capital.⁵

Finally, in line with the contract established between the representative bank and each entrepreneur, we assume that all bank's assets and liabilities have the same, one period, maturity.

Following Berka and Zimmermann (2005)'s specification of deposit insurance cost, the bank's objective is then given by:

⁵It should be noted, however, that we maintain BGG's hypothesis (for comparative purposes), in which lenders, by avoiding both idiosyncratic and aggregate risks, do not default. By holding a diversified portfolio of loans, banks guarantee idiosyncratic risk diversification. The aggregate risk that could be associated to deposits, is passed on to the entrepreneurs. As for bank capital, its risk is borne by the representative household which owns stocks on the bank. Bolton and Freixas (2006), in a similar context of regulatory capital requirements, also consider perfectly diversified banks, which do not go bankrupt.

$$\begin{aligned} \max_{L_{t+1}, B_{t+1}, D_{t+1}, S_{t+1}} & \left(R_{t+1}^F L_{t+1} + R_{t+1} B_{t+1} - R_{t+1}^D D_{t+1} - E_t(R_{t+1}^S) S_{t+1} - \delta_e \frac{D_{t+1}}{S_{t+1}} D_{t+1} \right) \\ \text{s.t. } & L_{t+1} + B_{t+1} = D_{t+1} + S_{t+1} \text{ (balance sheet constraint)} \end{aligned} \quad (9)$$

$$\frac{S_{t+1}}{L_{t+1}} \geq \alpha_e \text{ (capital requirements)} \quad (10)$$

with $1 > \alpha_e > 0$ and $1 > \delta_e > 0$, and where

- L_{t+1} are the real loans granted to all firms from t to $t + 1$;
- B_{t+1} are the real government bonds held by the bank from t to $t + 1$;
- D_{t+1} are the real households' deposits;
- S_{t+1} is the real bank's capital;
- R_{t+1}^F is the required gross real return on loans between t and $t + 1$;
- R_{t+1} is the gross real return on government bonds (B_{t+1});
- R_{t+1}^D is the gross real return on deposits (D_{t+1});
- $E_t(R_{t+1}^S)$ is the expected real return on bank capital (S_{t+1});
- $\delta_e \frac{D_{t+1}}{S_{t+1}}$ is the deposit insurance rate;
- α_e is the imposed level of capital requirements.

Note that R_{t+1}^F differs from the non-default lending rate (Z_{t+1}): as has been derived above (see equation 2), the difference between the two is due to the possibility of entrepreneur's default and to the existence of monitoring cost, which are taken into account in R_{t+1}^F . The rate of return on bank capital, R_{t+1}^S , is conditional on the realization of date $t + 1$ state of nature whereas all the other rates of return are not (R_{t+1}^F , R_{t+1} and R_{t+1}^D are known in t).

The first order conditions of the interior solution (that is, the solution characterized by positive values of B_{t+1} , D_{t+1} , L_{t+1} and S_{t+1}) of this problem yield

$$R_{t+1} = R_{t+1}^D + 2\delta_e \left(\frac{D_{t+1}}{S_{t+1}} \right), \quad (11)$$

$$R_{t+1}^F = (1 - \alpha_e)R_{t+1} + \alpha_e E_t(R_{t+1}^S) - \alpha_e \delta_e \left(\frac{D_{t+1}}{S_{t+1}} \right)^2, \quad (12)$$

which satisfy the bank's zero profit condition. These two equations were obtained considering binding capital requirements, that is,

$$\frac{S_{t+1}}{L_{t+1}} = \alpha_e,$$

which, as we show below, proves indeed to be the case for reasonable values of the parameters.

Due to the introduction of binding capital requirements, the required return on lending, R_{t+1}^F , becomes dependent on a weighted average of the deposit return and the equity's expected return, whereas in BGG, R_{t+1}^F is equal to the riskless rate, R_{t+1}^D .

2.3 Households

The economy is composed of a continuum of infinitely lived identical risk averse households of length unity. Each household works, consumes, and invests its savings in assets which include deposits, that pay a real riskless rate of return between t and $t + 1$ of R_{t+1}^D , and (risky) shares of ownership of banks in the economy, that pay R_{t+1}^S .

For simplicity, we assume a representative household's instantaneous utility function separable in consumption, liquidity (in the form of deposits) and leisure:

$$U_t = \frac{C_t^{1-\sigma}}{1-\sigma} + \alpha_0 \frac{D_{t+1}^{1-\beta_0}}{1-\beta_0} + \alpha_1 \frac{(1-H_t^h)^{1-\beta_1}}{1-\beta_1},$$

where C_t denotes household real consumption, D_{t+1} the deposits (in real terms) held by the household from t to $t + 1$ and H_t^h the household hours worked (as a fraction of total time endowment).

The real level of deposits is included in the instantaneous utility function to indicate the existence of liquidity services from wealth held in the form of that asset. That is, despite yielding a gross return of R^D , deposits also serve transaction needs since currency is absent from our model: we assume that deposits can be used in an almost money like fashion to simplify a variety of transactions. In short, we are assuming that, when compared to bank capital, deposits have an advantage in terms of liquidity, similarly to Poterba and Rotemberg (1987) and, more recently, Van den Heuvel (2005).

The representative household chooses consumption, leisure and portfolio to maximize the expected lifetime utility (appropriately discounted) subject to an intertemporal budget constraint that reflects intertemporal allocation possibilities. The household's problem is then given by

$$\begin{aligned} \max_{C_t, H_t^h, D_{t+1}, S_{t+1}} \quad & E_t \sum_{k=0}^{\infty} \beta^k \left[\frac{(C_{t+k})^{1-\sigma}}{1-\sigma} + \alpha_0 \frac{(D_{t+k+1})^{1-\beta_0}}{1-\beta_0} + \alpha_1 \frac{(1-H_{t+k}^h)^{1-\beta_1}}{1-\beta_1} \right] \\ \text{s.t.} \quad & C_t = W_t^h H_t^h - T_t + \Pi_t + R_t^D D_t - D_{t+1} + R_t^S S_t - S_{t+1}, \end{aligned} \quad (13)$$

where $0 < \beta < 1$ is the subjective discount factor, W_t^h is the real wage, T_t represents lump sum taxes, Π_t dividends received from ownership of imperfect competitive retail firms, and S_t the real bank capital held by the household from $t-1$ to t .

The first order conditions of (13) are the following three:

$$(C_t)^{-\sigma} = \beta R_{t+1}^D E_t [(C_{t+1})^{-\sigma}] + \alpha_0 D_{t+1}^{-\beta_0}, \quad (14)$$

which takes into account that the gross real rate of return on deposits, R_{t+1}^D , is certain at time t (is known ahead of time);

$$(C_t)^{-\sigma} = \beta \{ E_t (R_{t+1}^S) E_t [(C_{t+1})^{-\sigma}] + \text{cov}_t (R_{t+1}^S, (C_{t+1})^{-\sigma}) \}; \quad (15)$$

and the labor supply

$$\alpha_1 (1 - H_t^h)^{-\beta_1} = (C_t)^{-\sigma} W_t^h. \quad (16)$$

In this representation, the expected excess return on the risky asset (bank capital) is linked both to the risk and liquidity premium, since it depends, on the one hand, on the covariance between the aggregate consumption and bank capital's return and, on the other hand, on deposits liquidity.

2.4 Return on Bank Capital

Before proceeding we can now specify the return on bank capital. The bank capital requirement constraint establishes that the representative bank must issue an amount of capital which covers α_e times the value of loans. Loans are thus financed by bank capital and deposits, and households, in turn, allocate their savings to those two financial assets. A spread between the expected real return on bank capital and the real return on deposits is, then, justified by the liquidity services provided by deposits and by the riskless return on this asset, *i.e.*, $E_t(R_{t+1}^S) - R_{t+1}^D > 0$.

In addition, we assume that the expected real returns of bank capital and physical capital are

equal:

$$E_t(R_{t+1}^S) = E_t(R_{t+1}^K). \quad (17)$$

Although physical capital is totally held by the entrepreneurs, if households could hold it, they would demand the same expected return on both physical and bank capital: since both returns are subject to the same aggregate risk and neither bank capital nor physical capital provide liquidity services to the household, equation (17) would correspond to the no-arbitrage condition.

2.5 General Equilibrium

Now, following the modeling strategy of BGG, we embed the solution of the partial equilibrium contracting problem within a dynamic new Keynesian general equilibrium model, also taking into account the results obtained in the household and the bank optimization problems.

As mentioned above, in each period t each entrepreneur j acquires physical capital, K_{t+1}^j , which is used in combination with hired labor to produce output in period $t + 1$. Following BGG, we specify each entrepreneur's investment decisions, under adjustment costs, assuming that each entrepreneur j purchases the capital goods from some other competitive firms, producers of capital. More specifically, each entrepreneur sells his entire stock of capital at the end of each period t to the capital producing firms at price \bar{Q}_t . These firms also purchase raw output as an input, I_t (total investment expenditures), and combine it with the aggregate capital stock in the economy (K_t) to produce new capital goods via the production function $\Xi\left(\frac{I_t}{K_t}\right) K_t$, where $\Xi(\cdot)$ is an increasing and concave function, with $\Xi(0) = 0$. The function $\Xi(\cdot)$ is concave in investment to capture the difficulty of quickly changing the level of capital installed in the firms (and is thus called the adjustment cost function). The new capital goods, jointly with the capital used to produce them, are then sold to each entrepreneur j at the price Q_t .⁶

In this context, the *aggregate capital stock* follows an intertemporal accumulation equation with external adjustment costs,

$$K_{t+1} = \Xi\left(\frac{I_t}{K_t}\right) K_t + (1 - \delta)K_t, \quad (18)$$

where δ denotes the depreciation rate. The introduction of adjustment costs permits variation in the price of a unit of capital in terms of the numeraire good, Q_t , which, derived from the first

⁶We ignore the "rental rate" ($\bar{Q}_t - Q_t$), since in steady state $\bar{Q} = Q = 1$ and around the steady state the difference between \bar{Q}_t and Q_t is second order.

order condition for investment for one of the capital producer firms mentioned above, is given by

$$Q_t = \frac{1}{\Xi' \left(\frac{I_t}{K_t} \right)}, \quad (19)$$

The price of capital is, thus, an increasing function of the quantity invested.

Aggregate Production Function The physical capital acquired at period t by each entrepreneur is then combined with labor to produce output in period $t+1$, by means of a constant returns to scale technology. This allows us to write the production function as an aggregate relationship:

$$Y_t = A_t K_t^\alpha H_t^{1-\alpha} \quad (20)$$

with $0 < \alpha < 1$ and where Y_t represents the aggregate output of wholesale goods, H_t the labor input and A_t an exogenous technology term.

The final output may then be either transformed into a single type of consumption good, invested, consumed by the government (G_t) or used in monitoring costs:

$$Y_t = C_t + C_t^e + I_t + G_t + \mu \Theta(\bar{\omega}_t) R_t^K Q_{t-1} K_t. \quad (21)$$

Entrepreneurs sell the output to retailers at a relative price of $\frac{1}{X_t}$, where X_t is the gross markup of retail goods over wholesale goods. Therefore, the expected gross return to holding a unit of capital from t to $t+1$ can be written as:

$$E_t (R_{t+1}^K) = E_t \left[\frac{\frac{1}{X_{t+1}} \alpha \frac{Y_{t+1}}{K_{t+1}} + Q_{t+1} (1 - \delta)}{Q_t} \right], \quad (22)$$

where $\frac{1}{X_{t+1}} \alpha \frac{Y_{t+1}}{K_{t+1}}$ represents the rent paid to a unit of capital in $t+1$.

In turn, as already mentioned, the supply of investment capital is described by the return on physical capital the (representative) bank requires in order to grant loans to the firms (see equation (5) on page 10).

Concerning the labor input, it is assumed that $H_t = (H_t^h)^\Omega (H_t^e)^{1-\Omega}$, with $1 < \Omega < 0$, and where H_t^h represents the households labor, and H_t^e the entrepreneurial labor. Therefore, we can rewrite (20) as

$$Y_t = A_t K_t^\alpha \left[(H_t^h)^\Omega (H_t^e)^{1-\Omega} \right]^{1-\alpha}. \quad (23)$$

Equating marginal product with the wage, for each case, we obtain:

$$W_{t+1}^h = (1 - \alpha)\Omega \frac{1}{X_{t+1}} \frac{Y_{t+1}}{H_{t+1}^h} \quad (24)$$

$$W_{t+1}^e = (1 - \alpha)(1 - \Omega) \frac{1}{X_{t+1}} \frac{Y_{t+1}}{H_{t+1}^e} \quad (25)$$

where W_{t+1}^h represents the real wage for households labor and W_{t+1}^e the real wage for entrepreneurial labor. As mentioned, and following BGG, we assume that entrepreneurs supply one unit of labor inelastically to the general labor market: $H_t^e = 1, \forall t$.

Now, taking into account equations (7), (20) and (25), we can rewrite (6) as

$$\begin{aligned} N_{t+1} = & \gamma \left[R_t^K Q_{t-1} K_t - R_t^F (Q_{t-1} K_t - N_t) - \mu \Theta(\bar{\omega}_t) R_t^K Q_{t-1} K_t \right] + \\ & + (1 - \alpha)(1 - \Omega) \frac{1}{X_t} A_t K_t^\alpha (H_t^h)^{\Omega(1-\alpha)}. \end{aligned} \quad (26)$$

The Retail Sector and Price Setting To increase the empirical relevance of the model concerning price inertia, we introduce sticky prices in it using standard devices used in new-Keynesian research. Namely, we incorporate monopolistic competition and costs of adjusting nominal prices by distinguishing between entrepreneurs and retailers (since assuming that entrepreneurs are imperfect competitors would complicate aggregation): entrepreneurs produce wholesale goods in competitive markets, and then sell their output to retailers who are monopolistic competitors. Retailers do nothing other than buy goods from entrepreneurs, differentiate them (costlessly), and then resell them to households. They are included only in order to introduce price inertia in a tractable manner: following Calvo (1983), it is assumed that the retailer is free to change its price in a given period only with probability $1 - \theta$ (with $0 < \theta < 1$). The profits from retail activity are rebated lump-sum to households (Π_t in the household's intertemporal budget constraint).⁷

Government Government comprises the monetary, fiscal and regulatory authorities. We assume that conflicts between policies are internalized within the agent government, since we do not aim at exploring those differences.

⁷Detailed derivation, not presented here since it is standard in new Keynesian framework, is available from the authors.

Public expenditures, G_t , are financed by lump-sum taxes, T_t , and by issuing securities (government bonds, B_{t+1}):

$$G_t = B_{t+1} - B_t R_t + T_t + J_t,$$

where J_t represents other costs and revenues and includes the deposit insurance premium paid by the banks to the regulatory authority. In particular, the government adjusts the mix of financing between bonds issuance and lump-sum taxes to support an interest rate monetary policy rule, to be defined below. To implement its choice of the nominal interest rate, the government adjusts the supply of government bonds to satisfy the bank's demand for this asset.

2.6 The Linearized Model and Calibration

According to the model just described, and in the absence of exogenous shocks, the economy converges to a steady state growth path, along which all variables are constant over time (including prices, which implies a zero inflation rate in steady state).

To linearize the preceding equations, we use a first order Taylor series expansion around the steady state. Let the lower case letters denote the percentage deviation of each variable from its steady state level: $x_t = \ln\left(\frac{X_t}{X}\right)$, where X , without the time subscript, is the value of X_t in nonstochastic steady state.

The complete log-linearized model is provided in the Appendix. Here we focus on the main equations necessary to clarify the results and discussion in the following sections.

Aggregate Demand

The aggregate demand is defined by equations (5), (8), (14), (15), (19), (21) and (22). The household's Euler equations (14) and (15) can be written in log-linear form as (assuming that $\sigma = \beta_0$):⁸

$$-\sigma c_t = -\sigma \beta R^D E_t(c_{t+1}) + \beta R^D r_{t+1}^D - \alpha_0 \sigma \left(\frac{C}{D}\right)^\sigma d_{t+1}, \quad (27)$$

$$-\sigma c_t = -\sigma \beta R^K E_t(c_{t+1}) + \beta R^K E_t(r_{t+1}^K). \quad (28)$$

⁸We take a first-order Taylor approximation around the steady state ignoring the second order terms (or assuming that they are constant over time: $cov_t(.) = cov(.), \forall t$). Thus, the difference between $E_t(r_{t+1}^K)$ and r_{t+1}^D rests solely on liquidity.

Recall that we assume that $E_t(R_{t+1}^S) = E_t(R_{t+1}^K)$, as argued above.

In what concerns the relationship between the external finance premium and the ratio of capital expenditures to net worth, equation (5) - p. 10 - becomes, in the log-linearized version of the model,

$$E_t(r_{t+1}^K) - r_{t+1}^F = v(k_{t+1} + q_t - n_{t+1}), \quad (29)$$

where v is the steady state elasticity of $\frac{E_t(R_{t+1}^K)}{R_{t+1}^F}$ with respect to $\frac{Q_t K_{t+1}}{N_{t+1}}$.

Representative Bank

Equations (11), p. 13, and (12), p. 13, derived from the first order conditions of the bank's profit maximization problem, can be written in log-linear form as:

$$r_{t+1} = \frac{R^D}{R} r_{t+1}^D + \frac{2\delta_e \frac{D}{S}}{R} (d_{t+1} - s_{t+1}) \quad (30)$$

$$r_{t+1}^F = \alpha_e \frac{R^K}{R^F} E_t(r_{t+1}^K) + (1 - \alpha_e) \frac{R}{R^F} r_{t+1} - \frac{2\alpha_e \delta_e \left(\frac{D}{S}\right)^2}{R^F} (d_{t+1} - s_{t+1}). \quad (31)$$

The capital requirement constraint $S_{t+1} = \alpha_e(Q_t K_{t+1} - N_{t+1})$, turns into:

$$s_{t+1} = \frac{K}{L} (k_{t+1} + q_t) - \frac{N}{L} n_{t+1}. \quad (32)$$

Aggregate Supply and State Variables

The aggregate supply is defined by the aggregate production function (23), the labor market clearing condition - taking into account both equations (16) and (24) - and the Phillips curve (or the price adjustment equation) derived from the optimal price setting by the retail sector.

The transition for the two state variables, capital and net worth, is described by equations (18) and (26), respectively.

The log-linearized version of these equations is provided in the Appendix.

Monetary Policy Rule

The interest rate rule is given by

$$r_{t+1}^n = \rho r_t^n + \varsigma \pi_{t-1} + \varepsilon_t^{r^n} \quad (33)$$

where $r_{t+1}^n \equiv r_{t+1} + E_t \pi_{t+1}$ is the nominal interest rate from t to $t+1$ (with $\pi_{t+1} \equiv p_{t+1} - p_t$) and $\varepsilon_t^{r^n}$ an i.i.d. disturbance at time t . As in BGG, we standardly assume that the current nominal interest rate responds to the lagged inflation rate and the lagged interest rate.

Calibration

We calibrate the model assuming that a period is a quarter. To evaluate the parameters and steady state (SS) variables common to the BGG's model, we followed these authors, focusing on U.S. data. See table 2 in the Appendix for details.

Other parameters and SS variables are specific to our model, namely, the ratio of loans to deposits in SS, the bank capital requirement and the deposit insurance costs parameters (α_e and δ_e , respectively) and the preference parameter, β_0 .

To compute the SS ratio of loans to deposits, $\frac{L}{D}$, we use data on commercial and industrial (C&I) loans made by all U.S. commercial banks - provided by the Survey of Terms of Business Lending that is published by the Federal Reserve⁹ - and data on the total loans and deposits at all U.S. commercial banks - available at the Federal Reserve Bank of St. Louis.¹⁰

To calibrate the deposit insurance parameter (δ_e) we followed Berka and Zimmermann (2005)'s procedure, using U.S. data as of December 2006, from the Federal Deposit Insurance Corporation (FDIC).

Concerning the bank capital requirement, we set α_e equal to 0.08 based on the rules established by the Basel Accords - see Basle Committee on Banking Supervision (1988, 2004).

Finally, in calibrating the preference parameters, we assume, for simplicity, that $\sigma = \beta$. By that, we only need to compute the deposit to consumption ratio in steady state ($\frac{D}{C}$) to solve the model, instead of defining both variables, C and D , separately. And, as in many business cycle models, including BGG, σ is set equal to 1 (log preferences).

For further details on the model's calibration see the Appendix.

After log-linearizing the model, we applied the computational procedure used for solving linear rational expectations models developed by McCallum (1999).

3 The Bank Capital Channel at Work

In order to analyze the role of bank capital in the transmission of monetary policy and, thus, in business cycle fluctuations, we present now some quantitative experiments focusing on the economy

⁹Available at <http://www.federalreserve.gov/releases/e2/>.

¹⁰See <http://research.stlouisfed.org/fred2/>.

response to an unanticipated temporary negative monetary policy shock.

Concerning the channels through which monetary policy affects real activity, our model, derived above, brings together *(i)* the standard interest rate channel of monetary policy transmission - according to which an unanticipated increase in the nominal interest rate depresses the demand for physical capital, which, in turn, reduces investment and the price of capital; *(ii)* the borrowers' balance sheet channel; and *(iii)* the bank capital channel.

The borrowers' balance sheet channel predicts that the decline in asset prices (physical capital price in our model), due to a contractionary monetary policy, decreases borrowers' net worth, raising the external finance premium and, consequently, forcing down investment. This, in turn, will reduce asset prices and borrowers' net worth, further pushing down investment, and thus giving rise to the financial accelerator effect, which amplifies the impact of the monetary shock on borrowers' spending decisions. Finally, the bank capital channel, in contrast with the borrowers' balance sheet channel, works through the supply of funds side and is related to the introduction of the specific role of banks in cyclical fluctuations, as implied by our model.

3.1 Simulating the amplification effects of a monetary policy shock

To analyze the bank capital channel, we begin by comparing the effects of a negative innovation in the nominal interest rate (which corresponds to an annual increase of 25 basis points) under three distinct hypotheses:

- Variant 1: Baseline model derived previously, assuming a risk-based capital ratio requirement of 8%;
- Variant 2: Model without capital requirements, *i.e.*, excluding the capital requirement constraint from the baseline model (equation 10);
- Variant 3: Model with no capital requirements nor financial accelerator, which is generated by fixing the external finance premium, in variant 2, at its steady state level. That is, under variant 3, the capital requirement constraint is absent from the model, and both the bank and each entrepreneur observe costlessly the return of the firm's project. This amounts to setting the parameter v , in the financial accelerator equation (29), to zero, since in the absence of capital market frictions the external finance premium should not respond to changes in the ratio of capital expenditures to net worth.

Figures 1 and 2 illustrate the impulse response functions of the relevant variables under these three variants (variant 1: solid line; variant 2: dashed line; and variant 3: dashed-dotted line),

using the calibrated model economy with each period equivalent to a quarter and the variables expressed as percentage deviations from steady state values.

The increase in the nominal interest rate triggers an immediate decline in output, investment and consumption below their steady-state values, after which the economy returns gradually to its steady state. As predicted by the Phillips curve in a sticky prices context, inflation also decreases in response to the output decline, and then gradually reverts to its stationary value. Inflation behavior, in turn, influences the nominal interest rate through the monetary policy rule - the monetary authority sets the nominal interest rate in response to lagged inflation and lagged nominal interest rate.

Figure 2 depicts the financial sector variables response. As in BGG, the external finance premium evolves countercyclically, increasing in response to the deterioration of entrepreneurs' financial position following the decline in assets prices. In fact, the financial accelerator effect of monetary policy (the borrowers' balance sheet channel), arising from the loan demand side and embedded within equation (29), is present in both variants 1 and 2. In line with the analysis in 2.1, above, this demand effect is based on the prediction that the external finance premium facing a borrower depends on the borrower's financial position - the greater the borrower's self-financing ratio is, the lower the external finance premium should be. Intuitively, a stronger financial position diminishes the expected monitoring costs that arise from the informational asymmetry between each entrepreneur and the bank.

However, it is notable that the impact of the monetary policy shock is stronger in the presence of capital requirements (that is, stronger in variant 1 than in variant 2). This amplification effect can be explained through the analysis of bank and household behavior, as follows.

Combining the log-linearized equations (30) and (31) which have been derived from the representative bank's profit maximization problem, it is straightforward to derive the following condition:

$$E_t(r_{t+1}^K) - r_{t+1}^F = \left(1 - \alpha_e \frac{R^K}{R^F}\right) E_t(r_{t+1}^K) - (1 - \alpha_e) \frac{R^D}{R^F} r_{t+1}^D - \left[(1 - \alpha_e) \frac{2\delta_e \frac{D}{S}}{R^F} - \frac{2\alpha_e \delta_e \left(\frac{D}{S}\right)^2}{R^F} \right] (d_{t+1} - s_{t+1}). \quad (34)$$

Taking into account the steady state conditions and the calibration of the model, we conclude that $\left(1 - \alpha_e \frac{R^K}{R^F}\right) \simeq (1 - \alpha_e) \frac{R^D}{R^F}$. More specifically, the difference between these two coefficients relies on the magnitude of the deposit insurance costs: when $\delta_e = 0.0000045$ and $\alpha_e = 0.08$,

these coefficients take the values 0.9194 and 0.9193, respectively. Therefore, equation (34) may be rewritten as

$$E_t(r_{t+1}^K) - r_{t+1}^F \simeq \left(1 - \alpha_e \frac{R^K}{R^F}\right) [E_t(r_{t+1}^K) - r_{t+1}^D] + \left[\frac{2\alpha_e \delta_e \left(\frac{D}{S}\right)^2}{R^F} - (1 - \alpha_e) \frac{2\delta_e \frac{D}{S}}{R^F}\right] (d_{t+1} - s_{t+1}). \quad (35)$$

According to this expression, the external finance premium, $E_t(r_{t+1}^K) - r_{t+1}^F$, depends positively on $E_t(r_{t+1}^K) - r_{t+1}^D$, which we will refer to as the liquidity premium.¹¹ The external finance premium also depends on the deposit-bank capital ratio, $d_{t+1} - s_{t+1}$, through the deposit insurance costs, but this effect is relatively small and vanishes when we set δ_e equal to zero.¹² Therefore, we focus our attention now on the relationship between the liquidity premium and the external finance premium.

As illustrated in figure 2, a contractionary monetary policy shock leads to an increase in the level of capital issued by the bank (s_{t+1}) in variant 1. This happens for two reasons: (i) the level of commercial and industrial (both uncollateralized) loans also increases - although entrepreneurs invest less [$\searrow (Q_t K_{t+1})$], the sharp decrease in their net worth ($\searrow N_{t+1}$) leads to an increase of $L_{t+1} (= Q_t K_{t+1} - N_{t+1})$ above its steady state level;¹³ and (ii) as bank capital requirements are binding in variant 1, the bank may only grant more credit if it issues more capital. To hold more bank capital during the recession, households in turn require an increase in the liquidity premium, $E_t(r_{t+1}^K) - r_{t+1}^D$, since they must reduce the amount of deposits to attenuate the decline in consumption (in line with Gorton and Winton, 2000's model, for instance).

To clarify this last effect recall the log-linearized Euler equations (27) and (28) derived in section 2. Combining these two equations, with the calibrated $\sigma = 1$, yields

¹¹Note that, since we use a first-order Taylor approximation around the steady state (ignoring the second order terms) to linearize the model, $E_t(r_{t+1}^K) - r_{t+1}^D$ is not the equity premium, defined as the extra return required by risk averse households to compensate for the covariance between equity returns and the stochastic discount factor. Instead, it reflects the liquidity advantage of deposits over bank capital, properly called liquidity premium.

¹²For example, in variant 1, the immediate change in deposit-bank capital ratio [second term on the right hand side of (35)] accounts for less than 1% of the change in the external finance premium. The absence of a significant impact is confirmed in an exercise, in the context of sensitivity analysis not reported here, where we compare different levels of capital requirements: choosing $\delta_e = 0.0000045$ (variant 1) or $\delta_e = 0$ leaves almost unchanged the impact of a decrease in α_e from 8% to 4%.

¹³See Gertler and Gilchrist (1993) and Den Haan *et al.* (2007) for some evidence on the increase of commercial and industrial loans after a contractionary monetary policy.

$$\beta R^K E_t(r_{t+1}^K) - \beta R^D r_{t+1}^D = (R^K - R^D) \beta E_t(c_{t+1}) - \alpha_0 \frac{C}{D} d_{t+1} \quad (36)$$

where $\alpha_0 \frac{C}{D} > 0$, which confirms that the liquidity premium required by the households depends negatively on deposits (d_{t+1}).

In sum, after the contractionary monetary policy shock in variant 1, the level of loans can only increase above its steady state level if the bank issues more capital (due to the binding capital requirements). Households in turn require an increase in the liquidity premium to hold more bank capital and less deposits - note that, as illustrated in figure 2, the liquidity premium under variant 1 increases with a simultaneous decrease in deposits' level and in the deposit-bank capital ratio. The larger the increase in the liquidity premium the larger will be the increase in the external finance premium (see equation 35):

$$\nearrow d_{t+1} \implies \nearrow [E_t(r_{t+1}^K) - r_{t+1}^D] \implies \nearrow [E_t(r_{t+1}^K) - r_{t+1}^F].$$

The bank's balance sheet equilibrium is guaranteed by a reduction in bonds held by the bank.

We call the relationship between deposits and the external finance premium (through the liquidity premium), the *liquidity premium effect*. This effect is strictly related to the financial accelerator effect. That is, in variant 1 of the model, the external finance premium increases not only because the net worth of firms decreases (due to the decline in asset prices), but also because the liquidity premium required by the households increases (a cost that is passed on to firms):

$$\begin{aligned} \text{(A) Liquidity Premium Effect: } \Delta^- D &\implies \Delta + \frac{E_t R_{t+1}^K}{R_{t+1}^D} \implies \Delta + \frac{E_t R_{t+1}^K}{R_{t+1}^F}. \\ \text{(B) Financial Accelerator Effect: } \Delta^- Q &\implies \Delta - \frac{N_{t+1}}{Q_t K_{t+1}} \implies \end{aligned}$$

Comparing variants 1 and 2 further clarifies the liquidity premium effect. Although the variant 2 of the model assumes no regulatory capital requirements, the bank still issues some capital due to the deposit insurance rate, which depends negatively on the level of bank capital: in steady state, for instance, the bank sets an equity-loan ratio of 3.2%, approximately. However, and in contrast with variant 1, the negative monetary shock in variant 2 leads to a decrease in bank capital, since banks are no longer forced to issue equity to finance a given percentage of loans. As illustrated in figure 2, after the negative shock both deposits and bank capital decrease in variant 2 (the increase in loans is compensated again by a decrease in bonds held by the bank), and the deposit-bank capital ratio increases (in contrast with variant 1).

Even though $d_{t+1} - s_{t+1}$ increases, in variant 2, the liquidity premium required by the households still rises after the shock, although less than in variant 1. This can again be explained through

the analysis of equation (36) above, according to which the liquidity premium required by the households depends negatively on d_{t+1} . In variant 2, households reduce the amount of bank capital held after the shock, and, consequently, reduce the level of deposits to a smaller extent than in variant 1. Therefore, the increase in the liquidity premium is smaller than in variant 1, as predicted by equation (36). This, in turn, implies a smaller increase in the external finance premium through effect (A) above, reducing the effects of the exogenous shock on investment and output (see figure 1).

We may then conclude that the introduction of regulatory capital requirements - in a model with bank capital, but where banks were not constrained by those requirements - amplifies the effects of monetary policy on real activity through the liquidity premium effect. Other experiments conducted by us, but not reported here, assuming different levels of risk-based capital requirements (α_e), show that the same conclusion applies to an exogenous increase in capital requirements imposed by the authorities (increase in α_e).

Finally, variant 3 excludes both the liquidity premium and the financial accelerator effects. As figures 1 and 2 show, there are considerable differences between variants 1 and 2, on the one hand, and variant 3, on the other. The effects of a monetary policy shock are much weaker in variant 3. Concerning, for instance, the immediate effect on real output and inflation, output decreases 1.44% in variant 1 and only 0.52% in variant 3, while inflation decreases 0.52% and 0.18% in variants 1 and 3, respectively.¹⁴

BGG predict that the financial accelerator amplifies monetary shocks by about 50% (in terms of real output response). According to Quadrini (2001), in his comment to Carlstrom and Fuerst (2001), 50% is still relatively small: "Based on this result, it is hard to claim that financial frictions are the main mechanism through which monetary shock get propagated in the economy. If we eliminate financial market frictions, the impact of monetary shocks will be reduced by only one third." (p. 31) Our model responds to this insufficiency. If we eliminate financial market frictions, that is, if we compare variant 3 with variants 1 and 2, the impact of the monetary shock is reduced by much more than one third: 63.63% and 56.84% from variants 1 and 2, respectively, to variant 3.

3.2 Decomposing the amplification effects

To confirm and then explain this discrepancy in the magnitude of results, we compare, in figure 3, the effects of the negative innovation in the nominal interest rate under variants 1, 3 and

¹⁴This difference in inflation response justifies the contrast in nominal interest rate behavior following the initial shock, shown in figure 1.

a BGG variant, that is, a variant derived as our baseline model but treating the bank as the financial intermediary in BGG's model, thus excluding bank capital and eliminating deposits from households' utility function.¹⁵

Variant 1 includes both the financial accelerator and the liquidity premium effects, variant BGG only comprises the financial accelerator effect and variant 3 excludes both effects (the external finance premium does not depart from its steady state value). Or, in other words, variant 1 comprises the effects arising from the loan demand side (due to the informational asymmetry between each entrepreneur and the bank, which gives rise to the financial accelerator effect) and the effects arising from the loan supply side (due to the presence of bank capital in the model, which gives rise to the liquidity premium effect); variant BGG, in turn, only comprises loan demand effects and variant 3 excludes both effects.

As illustrated in figure 3, the real effects of monetary policy are in fact much stronger in variant 1 than in variant BGG: concerning real output, once more, whereas it initially decreases 1.44% in variant 1, it only decreases 0.685% in variant BGG. In other words, whereas the introduction of an informational asymmetry between each entrepreneur and the bank amplifies monetary shocks by about 30% in our model (variant BGG *vs* variant 3), the introduction of that same information asymmetry jointly with the imposition of bank capital minimum levels (through a deposit insurance rate and capital requirements) amplifies monetary shocks by significantly more than 100% (variant 1 *vs* variant 3).¹⁶

In variant 1 the external finance premium set by the bank must not only compensate the bank for the costs of mitigating incentive problems due to informational asymmetries (as in variant BGG), but also the return required by the households to hold bank capital. That is, the external finance premium, in variant 1, is not only influenced by the self financing ratio, $\frac{N_{t+1}}{Q_t K_{t+1}}$, but also by the liquidity premium required by the households, $\frac{E_t R_{t+1}^K}{R_{t+1}^D}$. Since the liquidity premium required by the households is countercyclical in variant 1 (see figure 2), due to deposits response, the countercyclical movement in the external finance premium is exacerbated (see figure 3: the external finance premium initially increases 0.066% in variant 1 *vs* 0.036% in variant BGG). This explains why real effects are much stronger in variant 1 than in variant BGG.

In sum, the amplification effects are much stronger in variant 1 (as well as in variant 2) than

¹⁵Although in BGG's original model, real money balances are included in the utility function, the results are similar to those obtained under the BGG variant: under interest rate targeting, money in the utility function yields a money demand equation, which "simply determines the path of the nominal money stock. To implement its choice of the nominal interest rate, the central bank adjusts the money stock to satisfy this equation." (Bernanke *et al.*, 1999, p. 1364).

¹⁶The behavior of the nominal interest rate after the initial period is, once more, justified by the response of inflation, which is much stronger in variant 1 than in variants 3 and BGG.

in variant BGG. The reason is summarized in Table 1: in addition to the borrowers' balance sheet channel of monetary policy transmission (also included in variant BGG), variants 1 and 2 comprise the *bank capital channel*, which, through the liquidity premium effect, further amplifies the monetary policy shock effects. In turn, the amplifying effects are somewhat stronger in variant 1 than in 2, since in variant 1 banks must issue more capital to comply with the binding capital requirements.

	Standard interest rate channel	Borrowers' balance sheet channel (amplifiers of monetary policy effects)	Bank capital channel
Variant 1	✓	✓	✓
Variant 2	✓	✓	✓
Variant 3	✓		
Variant BGG	✓	✓	

Table 1: Monetary policy transmission channels

Our result of a much more powerful propagation than in BGG's model, is in line with Kocherlakota (2000)'s argument - credit constraints can help to explain the properties of output fluctuations in the U.S., including the large movements in aggregate output. According to this author, these large movements cannot be explained by large shocks (those "are hard to find in the data," p. 3), but by mechanisms which transform "small, barely detectable, shocks to some or all parts of the economy into large, persistent, asymmetric movements in aggregate output."

As for persistence over time of the effects of the monetary policy shock, using the half-life (from the initial impact) criterion, as in Carlstrom and Fuerst (2001), none of the amplification channels generate higher persistence: the output response, for instance, reaches half life between the second and the third quarters in variants 1, 2, 3 and BGG.

3.3 Confirming that capital requirements are binding

As the results of our model rely on the assumption of binding capital requirements, we show now that, for reasonable values of the parameters, capital requirements are in fact binding in our model. In the absence of deposit insurance, this is straightforward to show: with no regulatory capital requirements nor deposit insurance, banks clearly prefer to finance loans with deposits, since, due to the liquidity premium, $R_{t+1}^D < E_t(R_{t+1}^S)$, that is, deposits are less expensive than bank capital. Therefore, there is no reason for banks to hold bank capital and, consequently, $S_{t+1} = 0$. If the capital requirement constraint is introduced, then banks should optimally set S_{t+1} at its minimum

regulatory level.

When deposit insurance costs are introduced, the outcome depends on the value assumed for the deposit insurance costs parameter, δ_e , which enters the bank's profit function. In the absence of capital requirements and considering the calibrated value of δ_e (0.0000045, associated with an adequately capitalized bank belonging to the subgroup A, as defined by FDIC for the soundest financial institutions, as of December 2006), bank issues bank capital, in steady state, such that $S = 0.0317L$. That is, bank capital is set below the regulatory level. We also verify that bank capital remains always well below its minimum regulatory level, in the absence of regulatory capital requirements, when one of the following exogenous shocks is simulated: a contractionary or an expansionary monetary policy shock,¹⁷ an expansionary or contractionary government expenditure shock, and an expansionary or contractionary technology shock. Therefore, when the regulatory capital constraint is introduced it will be binding: $S_{t+1} = 0.08L_{t+1}$.

Other experiments conducted by us, but not reported here, show that by considering binding capital requirements our model rules out the analysis of unsound financial institutions, as banks belonging to the subgroup C as defined by the FDIC, which consists of institutions that pose a substantial probability of loss to the deposit insurance fund, and, thus, face a higher δ_e . Excluding this hypothesis seems reasonable, in the context of our model, since a bank of type C will most probably face additional restrictions when issuing new capital, restrictions which we do not take into account.

In addition, we have also performed the following sensitivity and robustness checks:

- Introducing a permanent technology shock and a temporary shock to government expenditures, as defined in the Appendix;
- Removing the adjustment costs in the production of capital (which leads to a constant price of capital);
- Considering internal habit formation in consumption and modifying investment adjustment costs, making them directly dependent on changes in investment, as in Christiano *et al.* (2005).

The results obtained indicate that the bank capital channel remains at work in all of the above experiments: the liquidity premium effect amplifies the effects of the exogenous shock considered. Besides, combining habit formation in consumption with Christiano *et al.*'s investment adjustment

¹⁷Corresponding, respectively, to an annual increase or decrease in the nominal interest rate of 25 basis points.

costs, generates more empirically consistent hump-shaped responses of investment, consumption and, consequently, output, to a negative innovation in the nominal interest rate.

4 The Liquidity Premium Amplification Effect: Basel I *vs* Basel II

The bank capital regulation framework established by Basel I, established banks' obligation to continually meet a risk based capital requirement. In short, under Basel I, each bank must maintain a total risk weighted capital ratio, defined as the ratio of bank capital to the bank's risk-weighted assets, of at least 8%. The weights for assets on the balance sheet depend, in turn, on the institutional nature of the borrower. For example, a zero weight is assigned to a government security issued in the OECD, meaning that the bank can finance such asset through deposits without adding any capital. Other three weights are permitted, all meant to reflect credit risk: 0.2 (*e.g.*, for interbank loans in OECD countries), 0.5 (*e.g.*, for loans fully secured by mortgages on residential property) and 1 (*e.g.*, for industrial and commercial loans).¹⁸

As the same risk weight applies to all loans of each category ('one size fits all' approach), Basel I rules do not reflect the risk that each particular borrower poses to the bank. This has created the incentive for arbitrage activities: by moving low-risk instruments off balance sheet and retain only relatively high-risk instruments, banks were able to increase the risk to which they were exposed without increasing the amount of regulatory capital.

According to Jones (2000), from a regulatory perspective, capital arbitrage has undermined the effectiveness of Basel I. At least for large banks, capital ratios under this framework are no longer reliable measures of capital adequacy: although for most banking organizations, neither public financial reports nor regulatory reports disclose sufficient information to measure the full extent of a bank's capital arbitrage activities, available evidence suggests that the volume of this type of activities is large and growing rapidly, especially among the largest banks. Furthermore, recent innovation in financial markets is making capital arbitrage more accessible to a much broader range of banks than in the past.

Basel II, aiming to further foster stability in the international banking system, addresses these shortcomings. One of the core changes proposed by Basel II is the increased sensitivity of a bank's capital requirement to the risk of its assets: the amount of capital that a bank has to hold against a

¹⁸See Basle Committee on Banking Supervision (1988), for a detailed description of the rules introduced by Basel I, and Dewatripont and Tirole (1994), for a short review.

given exposure becomes a function of the estimated credit risk of that exposure. Consequently, the constant risk weight of 100% for commercial and industrial (C&I) loans, for instance, is replaced by a variable weight, so that the C&I loans with a low credit rating and a high probability of default are thus assigned a high risk weight. That is, under Basel II, the risk weights used to compute banks' capital requirements are determined both by the category of borrower and by the riskiness of a particular borrower, thereby aiming to reduce regulatory capital arbitrage.¹⁹

The introduction of the new bank capital requirements rules may however accentuate the procyclical tendencies of banking, with potential macroeconomic consequences, as the countercyclical risk weights used to compute capital requirements may exacerbate the procyclical fluctuations in bank lending. Under Basel II, the co-movement of capital requirements and the business cycle could induce banks to further reduce lending during recessions due to high capital requirements.

The baseline model developed in section 2 can be extended to compare the role of bank capital in the business cycle under Basel I *versus* Basel II. In fact, on the one hand, the capital requirements on that baseline version can be interpreted as a simplified Basel I rule: banks must hold an amount of equity of at least 8% of the amount of C&I loans, so that the same risk weight (100%) always applies to these loans, while government bonds, bearing no risk, have zero weight. On the other hand, by introducing, in the capital requirements constraint, risk weights that vary over the business cycle, the model can be extended in order to shed light on the potential procyclicality of Basel II. We proceed now in this direction.

Under Basel II rules, the risk weights in the capital requirements constraint depend on the estimated credit risk of each exposure. In our model, firms default on the loan if the idiosyncratic disturbance, ω_{t+1}^j , turns out to be smaller than the cutoff value $\bar{\omega}_{t+1}^j$. This cutoff value, in turn, depends positively on the ratio of capital expenditures to net worth, $\left(\frac{Q_t K_{t+1}^j}{N_{t+1}^j}\right)$, which, for simplicity, we refer to as the leverage ratio.²⁰ Therefore, the risk weights in the capital requirements constraint become a positive function of the leverage ratio.

Note that the optimal financial contract established between the bank and each entrepreneur yields a common cutoff value, $\bar{\omega}_{t+1}$, for all entrepreneurs. Combining equations (3) and (4) yields

¹⁹See Basle Committee on Banking Supervision (2004) for details.

²⁰Intuitively, everything else equal, higher leverage means higher exposure, implying a higher probability of default, which the bank translates into a higher cutoff value. The formal proof, similar to the one in BBG's Appendix A, is available from the authors.

$$\begin{aligned} & \left\{ [1 - F(\bar{\omega}_{t+1}^j)] \bar{\omega}_{t+1}^j + (1 - \mu) \int_0^{\bar{\omega}_{t+1}^j} \omega_{t+1}^j f(\omega) d\omega \right\} R_{t+1}^K \varphi \left(\frac{E_t(R_{t+1}^K)}{R_{t+1}^F} \right) = \\ & = R_{t+1}^F \left[\varphi \left(\frac{E_t(R_{t+1}^K)}{R_{t+1}^F} \right) - 1 \right]. \end{aligned}$$

The right hand side of the former equation is the same for all firms (it does not depend on j). Concerning the left hand side, it is straightforward to show that, for an interior solution of $\bar{\omega}_{t+1}$, it is increasing in $\bar{\omega}_{t+1}^j$ (formal proof available upon request). Therefore, there exists only one $\bar{\omega}_{t+1}^j$ that satisfies the former equation: $\bar{\omega}_{t+1}^j = \bar{\omega}_{t+1}, \forall j$. The intuition is that, facing a common discounted return, $\frac{E_t(R_{t+1}^K)}{R_{t+1}^F}$, producers choose the same leverage ratio, leading to a common cutoff value; larger firms, rather than benefiting from lower interest rates, have, instead, access to larger amounts of credit.

Yet, the common cutoff value and, consequently, the credit risk, vary with the business cycle. This allows straightaway the analysis of the business cycle properties of Basel II, insulated from the effects of credit risk heterogeneity across firms.

According to the Internal Ratings Based (IRB) approach of Basel II, the estimated credit risk and, consequently, the risk weights used to compute capital requirements, are assumed to be a function of four parameters associated with each loan: the probability of default (PD), the loss given default (LGD), the exposure at default (EAD) and the loan's maturity (M). Banks adopting the advanced variant of the IRB approach are responsible for calculating all four of these parameters themselves, using their own internal rating models. Banks adopting the foundation variant of the IRB approach are only responsible for calculating the PD parameter, while the other three parameters are to be set by the Basel Committee on Banking Supervision. As in Basel I, the ratio of bank capital to the risk-weighted assets must be at least 8%. The risk-weighted assets are, in turn, computed as follows.

1. The capital requirement for corporate exposures, under the assumption of one-year maturity, is given by²¹

$$CR = LGD \times \Phi \left[(1 - \tau)^{-0.5} \times \Phi^{-1}(PD) + \left(\frac{\tau}{1 - \tau} \right)^{0.5} \Phi^{-1}(0.999) \right] - PD \times LGD,$$

where $\Phi(\cdot)$ denotes the cumulative distribution function for a standard normal random vari-

²¹See Basle Committee on Banking Supervision (2004), paragraph 272, for details.

able and τ represents the asset-value correlation which parameterizes dependence across borrowers and is assumed to be a decreasing function of the PD :

$$\tau = \frac{0.12 \times (1 - \exp(-50 \times PD))}{1 - \exp(-50)} + 0.24 \left[1 - \frac{(1 - \exp(-50 \times PD))}{1 - \exp(-50)} \right].$$

2. According to the foundation variant of the IRB approach, the LGD is set to 0.45 to all corporate exposures. Basel II also establishes that the expected losses $PD \times LGD$ should be covered with loss general provision. From the perspective of our work, provisions are treated as bank capital. Therefore, the capital requirement becomes

$$CR = 0.45 \times \Phi \left[(1 - \tau)^{-0.5} \times \Phi^{-1}(PD) + \left(\frac{\tau}{1 - \tau} \right)^{0.5} \Phi^{-1}(0.999) \right].$$

3. The risk-weighted assets are then given by $CR \times 12.5 \times EAD$.

Since all firms in our model have the same leverage ratio and, thus, the same probability of default (the same cutoff value $\bar{\omega}$), they are all assigned the same CR . The bank capital requirement constraint can thus be defined as

$$\frac{S_{t+1}}{CR_{t+1} \times 12.5 \times L_{t+1}} \geq 0.08 \iff \frac{S_{t+1}}{CR_{t+1}^* \times L_{t+1}} \geq 0.08,$$

where L_{t+1} are the loans granted by the bank to all firms from t to $t + 1$, S_{t+1} is the bank's capital and $CR_{t+1}^* = CR_{t+1} \times 12.5$.

By keeping track of how CR^* evolves over the business cycle, our model is able to give some insight into procyclicality of Basel II.

Note that under the foundation variant of the IRB approach of Basel II, CR_{t+1}^* only varies with PD_{t+1} . As mentioned, the probability of default on each loan in our model, $prob(\omega_{t+1}^j < \bar{\omega}_{t+1})$, depends positively on the cutoff value $\bar{\omega}_{t+1}$, which, in turn, depends positively on firm's leverage ratio, $\frac{Q_t K_{t+1}}{N_{t+1}}$. In sum, the higher the leverage ratio, the higher the probability of default, that is, the higher the credit risk. The optimal financial contract established between the bank and each entrepreneur can thus be used to derive a positive relationship between CR_{t+1}^* and $\frac{Q_t K_{t+1}}{N_{t+1}}$ as reported in Figure 6.

According to our simulations, this relationship can be approximated by the linear function

$$CR_{t+1}^* = a + b \frac{Q_t K_{t+1}}{N_{t+1}},$$

with $a = -1.6474$ and $b = 1.2371$. Consequently, the capital requirements constraint in the bank's objective, under Basel II, becomes:

$$\frac{S_{t+1}}{L_{t+1}} \geq 0.08 \left(a + b \frac{Q_t K_{t+1}}{N_{t+1}} \right). \quad (37)$$

The calibrated model delivers, in steady state, a smaller minimum ratio of bank capital to loans than in Basel I (0.072 *vs* 0.08 under Basel I), which is in line with the results of Committee of European Banking Supervisors (2006), for instance. Besides, the ratio of bank capital to bank loans, as defined by equation (37), fluctuates over the business cycle, in contrast with Basel I. Specifically, the higher the leverage ratio, the higher the fraction of loans which must be financed by bank capital.

The bank's objective is now given by:

$$\begin{aligned} \max_{L_{t+1}, B_{t+1}, D_{t+1}, S_{t+1}} & \left(R_{t+1}^F L_{t+1} + R_{t+1} B_{t+1} - R_{t+1}^D D_{t+1} - E_t(R_{t+1}^S) S_{t+1} - \delta_e \frac{D_{t+1}}{S_{t+1}} D_{t+1} \right) \\ \text{s.t. } & L_{t+1} + B_{t+1} = D_{t+1} + S_{t+1} \text{ (balance sheet constraint)} \\ & \frac{S_{t+1}}{L_{t+1}} \geq 0.08 \left(a + b \frac{Q_t K_{t+1}}{N_{t+1}} \right) \text{ (capital requirements)} \end{aligned} \quad (38)$$

Taking into account that the leverage ratio depends, in turn, on the loans granted to firms, since $L_{t+1} = Q_t K_{t+1} - N_{t+1}$, the capital requirement constraint in this problem can be rewritten as:

$$\frac{S_{t+1}}{L_{t+1}} \geq 0.08 \left[a + b \left(\frac{L_{t+1}}{N_{t+1}} + 1 \right) \right].$$

The first order conditions of the interior solution of problem (38) yield²²

$$R_{t+1} = R_{t+1}^D + 2\delta_e \left(\frac{D_{t+1}}{S_{t+1}} \right), \quad (39)$$

²²The two equations were derived considering binding capital requirements, since the analysis in 3.3 also applies here. In contrast with the bank's problem under Basel I, the bank's zero profit condition is not guaranteed here. Technically, we assume that profits are distributed to the households.

$$\begin{aligned}
R_{t+1}^F = & \left[1 - 0.08 \left(a - b + 2b \frac{Q_t K_{t+1}}{N_{t+1}} \right) \right] R_{t+1} + 0.08 \left(a - b + 2b \frac{Q_t K_{t+1}}{N_{t+1}} \right) E_t (R_{t+1}^S) - \\
& - 0.08 \delta_e \left(a - b + 2b \frac{Q_t K_{t+1}}{N_{t+1}} \right) \left(\frac{D_{t+1}}{S_{t+1}} \right)^2.
\end{aligned} \tag{40}$$

As in Basel I, the required return on lending, R_{t+1}^F , depends on a weighted average of the deposit's return and the bank capital's expected return. However, the weights depend now on firms' leverage. In particular, and taking into account the log-linearized version of equation (40) - see equation (42) in the Appendix -, the higher the firms' leverage, that is, the higher the credit risk, the higher the required return on lending by banks.

To analyze the consequences on the business cycle of introducing Basel II rules, we compare the effects of a negative innovation in the nominal interest rate, corresponding to an annual increase of 25 basis points, under Basel I, that is, considering the model developed in Section 2, and Basel II. Figures 4 and 5 illustrate the impulse response functions of the relevant variables under the two hypotheses. The response of both economic and financial variables under Basel II is much more pronounced than in Basel I, thus supporting the procyclicality hypothesis of Basel II.

Recall that under Basel II, bank capital depends positively, not only on the level of loans, but also on the firms' leverage (see equation 37, above). Since both loans and firms' leverage tend to increase after the contractionary shock, for the same reasons described in Section 3, the response of bank capital is amplified under Basel II, as illustrated in figure 5. As described in 3.1, to hold more bank capital during the recession, households require an increase in the liquidity premium, since they must reduce the amount of deposits held in order to attenuate the decline in consumption. In fact, figure 5 shows that the amplified increase in bank capital after the shock, under Basel II, leads to an amplified decrease in deposits and, consequently, to a marked increase in the liquidity premium required by households.

As in the baseline model, the increase in the liquidity premium leads, in turn, to an increase in the external finance premium faced by firms: combining the log-linearized versions of equations (39) and (40) - see the Appendix - yields

$$\begin{aligned}
E_t(r_{t+1}^K) - r_{t+1}^F &\simeq \left(1 - 0.08 \times B \frac{R^K}{R^F}\right) [E_t(r_{t+1}^K) - r_{t+1}^D] + \\
&+ \left[\frac{2 \times 0.08 B \delta_e \left(\frac{D}{S}\right)^2}{R^F} - (1 - 0.08 B) \frac{2 \delta_e \frac{D}{S}}{R^F} \right] (d_{t+1} - s_{t+1}) - \\
&- 0.08 \times 2b \frac{R^K - R - \delta_e \left(\frac{D}{S}\right)^2}{R^F} \frac{QK}{N} lev_{t+1}
\end{aligned}$$

where $B = a - b + 2b \frac{QK}{N}$, and $lev_{t+1} = q_t + k_{t+1} - n_{t+1}$. According to this equation, the external finance premium, $E_t(r_{t+1}^K) - r_{t+1}^F$, depends on the liquidity premium, $E_t(r_{t+1}^K) - r_{t+1}^D$, on the deposit-bank capital ratio, $d_{t+1} - s_{t+1}$, and on firms' leverage, lev_{t+1} . Again, these two latter effects are relatively small when compared to the former one.²³

In sum, our model predicts that after the contractionary shock banks must issue more capital under Basel II than under Basel I, since (i) the level of uncollateralized loans increases, (ii) firms' credit risk increases, and (iii) bank capital requirements are binding. In order to hold more bank capital, households require a higher increase in the liquidity premium, which, in turn, leads to a higher increase in the external finance premium faced by firms. Consequently, the liquidity premium effect which underlies the bank capital channel, detailed in 3.1, is stronger under Basel II, leading to more amplified responses of both economic and financial variables after the monetary shock.

This outcome supports the hypothesis, mentioned above in the introduction, that the application of the new bank capital requirements rules proposed by Basel II will accentuate the procyclical tendencies of banking, which may work against the main objective of Basel II of promoting the stability of the international banking system. In fact, the countercyclically risk weights used to compute capital requirements may lead banks to hold too much capital during downturns and less capital during upturns, when the danger of a systemic crises is larger, as argued by Danielsson *et al.* (2001).

²³For instance, immediately after the negative shock, the equation above can be rewritten as:

$$\begin{aligned}
E_t(r_{t+1}^K) - r_{t+1}^F &\simeq 0.82189 [E_t(r_{t+1}^K) - r_{t+1}^D] + 0.00040 (d_{t+1} - s_{t+1}) - 0.002926 lev_{t+1} \iff \\
0.13043 &\simeq 0.15063 + (-0.01255) - 0.00757
\end{aligned}$$

5 Concluding Remarks

Focusing on how microeconomic structures - namely the banks funding structure and the relationship between the banks, entrepreneurs and households - interact with macroeconomic business conditions, we have built a bank capital channel into a general equilibrium model, and found that it amplifies the real effects of monetary policy shocks and business cycle fluctuations, through a liquidity premium effect. This effect is strictly related to the financial accelerator effect associated with the borrowers' balance sheet channel: when the liquidity premium and the financial accelerator effects are both present, the external finance premium responds not only to borrowers' financial position (as in Bernanke *et al.*, 1999), but also to the liquidity premium required by households to hold bank capital. This exacerbates the (countercyclical) response of the external finance premium to a monetary policy shock, since the liquidity premium also moves countercyclically and influences positively the external finance premium.

The liquidity premium effect rests on the fact that bank capital (mandatory due to risk-based capital requirements) is more expensive to raise than deposits, due to households' preferences for liquidity, and that this difference tends to widen (narrow) during a recession (expansion): after a contractionary monetary policy shock, for instance, households tend to decrease the amount of deposits held to attenuate the decline in consumption; since we assume that deposits provide liquidity services, the households, thus, require an increase in liquidity premium, that is, an increase in the difference between the expected return on bank capital (which is also owned by households, but which does not render any liquidity services) and the return on deposits. This cost is then passed on to firms by the bank through an increase of the external finance premium.

Concerning the magnitude of the amplification effects, our results indicate that if we bring together the bank capital with the borrowers' balance sheet channel, financial frictions do seem to be a very important mechanism through which monetary shocks get propagated in the economy and business cycle fluctuations are amplified. Actually, if, in addition to the informational asymmetry between each entrepreneur and his bank, we introduce in the model other financial frictions related to the imposition of regulatory bank capital minimum levels, the role of financial frictions in the mechanism through which monetary shocks are propagated in the economy becomes much more powerful than in Bernanke *et al.*'s model, in line with some arguments in related literature.

As the definition of bank capital minimum levels has been the focus of Basel I and Basel II, we have extended the model in order to compare a simplified version of these two regulatory frameworks, thereby contributing to the debate on the procyclicality of Basel II. We found that the liquidity premium effect amplifies business cycle fluctuations the more significantly the closer

the regulatory rules are to Basel II, rather than to Basel I. For instance, in face of a contractionary shock, banks must issue more capital under Basel II than under Basel I. To absorb this additional capital, households require a higher increase in the liquidity premium, which, in turn, leads to a higher increase in the external finance premium faced by firms. This result implies that the application of the new bank capital requirements rules will accentuate the procyclical tendencies of banking, which conflicts with the main objective of Basel II of promoting the stability of the international banking system.

Economic policy conclusions should be drawn carefully, however, since the model simplifies and abstracts from many important features of the economy. Importantly, as the model is not designed to capture the effectiveness of Basel I and Basel II in preventing bank failure, conclusions regarding the ranking of the two frameworks are clearly out of its scope. As a matter of fact, our analysis has not been concerned with questions such as whether bank regulation is itself optimal and what type of regulation is more appropriate. We ignore risk and incentives that support capital adequacy regulation (as the social cost of bank failure) and, therefore, our analysis does not support any normative conclusions regarding bank-capital regulation.

So far, the value added by our work to the discussion of the role of financial imperfections in the monetary policy transmission mechanism and in business cycle fluctuations, and to the issue of procyclicality of Basel II, encourages to proceed this research. A promising direction is to build risk sensitive capital requirements into a heterogenous agent general equilibrium model. This will allow a fuller account of Basel II rules, by considering that credit risk varies not only along the business cycle, but also across firms.

Appendix: The Linearized Model and Calibration

A. The baseline model

To linearize the model's equations, we use a first order Taylor series expansion around the steady state. Let the lower case letters denote the percentage deviation of each variable from its steady state level: $x_t = \ln\left(\frac{X_t}{X}\right)$, where X is the value of X_t in nonstochastic steady state.

Aggregate Demand

Starting by log-linearizing the Euler equations, equation (14) becomes (assuming that $\sigma = \beta_0$):

$$-\sigma c_t = -\sigma \beta R^D E_t(c_{t+1}) + \beta R^D r_{t+1}^D - \alpha_0 \sigma \left(\frac{C}{D}\right)^\sigma d_{t+1}.$$

Concerning equation (15), we take a first-order Taylor approximation around the steady state ignoring the second order terms (or assuming that they are constant over time: $cov_t(.) = cov(.), \forall t$) and obtain:

$$-\sigma c_t = -\sigma \beta R^K E_t(c_{t+1}) + \beta R^K E_t(r_{t+1}^K).$$

Concerning the entrepreneurs' consumption (equation 8), we follow BGG and assume in simulations that

$$c_t^e = n_{t+1}.$$

In turn, the aggregate resource constraint (21) becomes

$$y_t = \frac{C}{Y} c_t + \frac{I}{Y} i_t + \frac{C^e}{Y} c_t^e + \frac{G}{Y} g_t + \xi_t^y,$$

where

$$\xi_t^y = \frac{\mu \Theta(\bar{\omega}) K R^K}{Y} \left[\ln \left(\frac{\mu \Theta(\bar{\omega}_t) Q_{t-1} K_t R_t^K}{\mu \Theta(\bar{\omega}) K R^K} \right) \right].$$

This term (ξ_t^y) is ignored in the simulations. Note that $\frac{\mu \Theta(\bar{\omega}) K R^K}{Y}$, the share of expected monitoring costs in output, is quite small (even smaller than $\frac{C^e}{Y}$).

In what concerns the relationship between the external finance premium and the ratio of capital expenditures to net worth, equation (5) can be written in log-linear form as

$$E_t(r_{t+1}^K) - r_{t+1}^F = v(k_{t+1} + q_t - n_{t+1}),$$

where v is the steady state elasticity of $\frac{E_t(R_{t+1}^K)}{R_{t+1}^F}$ with respect to $\frac{Q_t K_{t+1}}{N_{t+1}}$, *i.e.*, the steady state elasticity of the external finance premium with respect to the ratio of entrepreneurs' capital expenditures to net worth:

$$v = \frac{l'(\bar{\omega}_{SS})}{k'(\bar{\omega}_{SS})} \frac{k(\bar{\omega}_{SS})}{l(\bar{\omega}_{SS})}.$$

We follow Gertler *et al.* (2003) to compute v .

Log-linearization of (19) implies that

$$q_t = \varphi(i_t - k_t),$$

where φ is the elasticity of the price of capital with respect to $\frac{I}{K}$: $\varphi = -\frac{\Xi''(\frac{I}{K})}{\Xi'(\frac{I}{K})} \frac{I}{K}$.

Log-linearization of (22), in turn, renders

$$r_t^K = (1 - \varepsilon)(y_t - k_t - x_t) + \varepsilon q_t - q_{t-1}$$

with $\varepsilon = \frac{1-\delta}{(1-\delta)+\alpha \frac{Y}{XK}}$.

Aggregate Supply

In the log-linearized version of the model, equation (23) becomes

$$y_t = a_t + \alpha k_t + (1 - \alpha)\Omega h_t^h,$$

and the labor market clearing condition, taking into account both equations (16) and (24), is given by

$$\left(1 + \frac{1}{\eta}\right) h_t^h = y_t - x_t - \sigma c_t$$

where $\eta = \frac{\partial H^h}{\partial W^h} \frac{W^h}{H^h} = \frac{1}{\beta_1} \frac{1-H^h}{H^h}$.

Finally the Phillips curve (or the price adjustment equation) is given by

$$\pi_t = \beta E_t \pi_{t+1} - \kappa x_t,$$

where $\kappa = \frac{(1-\theta)(1-\beta\theta)}{\theta}$, $\pi_t \equiv p_t - p_{t-1}$ is the rate of inflation from $t-1$ to t , $p_t = \ln\left(\frac{P_t}{P}\right)$, and P is

the price index. This equation is derived from the optimal (staggered) price setting by the retail sector.

State Variables

Log-linearization of (26) implies that the entrepreneurs' net worth evolves according to (ignoring the monitoring costs):

$$\begin{aligned} n_{t+1} = & \gamma R^F n_t + \gamma R^F \left(1 - \frac{K}{N}\right) r_t^F + \\ & + \left(\gamma \frac{K}{N} R^K\right) r_t^K + \gamma \frac{K}{N} (R^K - R^F) q_{t-1} + \\ & + \gamma \frac{K}{N} (R^K - R^F) k_t + (1 - \alpha)(1 - \Omega) \frac{Y}{N} \frac{1}{X} (y_t - x_t). \end{aligned}$$

Concerning the capital stock, the log-linearized version of (18) is

$$k_t = \delta i_{t-1} + (1 - \delta) k_{t-1}.$$

Representative Bank

Equations (11) and (12) can be written in log-linear form as :

$$\begin{aligned} r_{t+1} &= \frac{R^D}{R} r_{t+1}^D + \frac{2\delta_e \frac{D}{S}}{R} (d_{t+1} - s_{t+1}) \\ r_{t+1}^F &= \alpha_e \frac{R^K}{R^F} E_t (r_{t+1}^K) + (1 - \alpha_e) \frac{R}{R^F} r_{t+1} - \frac{2\alpha_e \delta_e \left(\frac{D}{S}\right)^2}{R^F} (d_{t+1} - s_{t+1}). \end{aligned}$$

The capital requirement constraint, $S_{t+1} = \alpha_e (Q_t K_{t+1} - N_{t+1})$, turns into:

$$s_{t+1} = \frac{K}{L} (k_{t+1} + q_t) - \frac{N}{L} n_{t+1}.$$

Monetary Policy Rule and Shock Processes

The interest rate rule is given by

$$r_{t+1}^n = \rho r_t^n + \varsigma \pi_{t-1} + \varepsilon_t^{r^n}$$

where $r_{t+1}^n \equiv r_{t+1} + E_t \pi_{t+1}$ is the nominal interest rate from t to $t+1$ (with $\pi_{t+1} \equiv p_{t+1} - p_t$) and $\varepsilon_t^{r^n}$ an i.i.d. disturbance at time t .

Concerning the exogenous disturbances to government spending and technology, they follow, as in BGG, stationary autoregressive processes:

$$\begin{aligned} g_t &= \rho_g g_{t-1} + \varepsilon_t^g \\ a_t &= \rho_a a_{t-1} + \varepsilon_t^a \end{aligned}$$

where ε_t^g and ε_t^a are i.i.d. disturbances.

B. The log-linearized equations of the Basel II extension

By log-linearizing equations (39) and (40), derived from the bank's objective first order conditions, we get:

$$r_{t+1} = \frac{R^D}{R} r_{t+1}^D + \frac{2\delta_e \frac{D}{S}}{R} (d_{t+1} - s_{t+1}) \quad (41)$$

$$\begin{aligned} r_{t+1}^F &= 0.08 \left(a - b + 2b \frac{QK}{N} \right) \frac{R^K}{R^F} E_t (r_{t+1}^K) + \left[1 - 0.08 \left(a - b + 2b \frac{QK}{N} \right) \right] \frac{R}{R^F} r_{t+1} - \\ &\quad - 2 \times 0.08 \delta_e \left(a - b + 2b \frac{QK}{N} \right) \left(\frac{D}{S} \right)^2 \frac{1}{R^F} (d_{t+1} - s_{t+1}) + \\ &\quad + 0.08 \times 2b \frac{R^K - R - \delta_e \left(\frac{D}{S} \right)^2 QK}{R^F} \frac{QK}{N} lev_{t+1}, \end{aligned} \quad (42)$$

where $lev_{t+1} = q_t + k_{t+1} - n_{t+1}$.

Additionally, the log-linearized version of the binding capital constraint is

$$s_{t+1} = \left(\frac{K}{L} + 0.08b \frac{L}{S} \frac{QK}{N} \right) (k_{t+1} + q_t) - \left(\frac{N}{L} + 0.08b \frac{L}{S} \frac{QK}{N} \right) n_{t+1}. \quad (43)$$

C. Calibration

To evaluate some of the model's parameters and variables in steady state (SS), we follow BGG, who, focusing on U.S. data, consider (recall that, according to our notation, a variable without the time subscript indicates its steady state value):

Entrepreneurial Consumption/Output in SS	$\frac{C^e}{Y}$	0.01
Government Expenditure/Output in SS	$\frac{G}{Y}$	0.2
Gross Markup of Retail Goods over the Wholesale Goods in SS	X	1.1
Price of Capital in SS	Q	1
Entrepreneurial Labor	H_t^e	1
Elasticity of the price of capital with respect to I/K	φ	0.25
Capital Share	α	0.35
Household Labor Share	$(1 - \alpha)\Omega$	0.64
Labor Supply Elasticity	η	3
Depreciation Rate	δ	0.025
Interest Rate Smoothing	ρ	0.9
Coefficient on inflation in the interest rate rule	ς	0.11
Prob. that an entrepreneur survives to the next quarter	γ	0.9728
Probability of a firm does not change its price within a given period	θ	0.75
Serial correlation parameter for technology shock	ρ_a	1
Serial correlation parameter for gov. expend. shock	ρ_g	0.95
Standard Deviation of $\ln(\omega)$	$\sigma_{\ln \omega}$	0.28
Monitoring Costs Parameter	μ	0.12
Preference Parameter	σ	1
Preference Parameter	β_1	1

Table 2: Calibration I

Concerning the parameters related to the financial contract, we choose the same values as BGG for the probability that an entrepreneur survives to the next quarter ($\gamma = 0.9728$) and for the monitoring cost parameter ($\mu = 0.12$). For the standard deviation of $\ln(\omega)$, we assume that $\sigma_{\ln \omega} = 0.28$. According to Carlstrom and Fuerst (1997), a standard deviation of ω of around 0.2 is comparable to the corresponding empirical standard deviation reported by Boyd and Smith (1994). These assumptions allowed us to approximate, with good accuracy, the three steady state outcomes pointed out by BGG: a financing premium of 2% per year; $\frac{K}{N} = 2$ (which implies a ratio of loans to capital expenditures, $\frac{L}{K}$, of 0.5) and an annualized business failure rate, $F(\bar{\omega}) = 3\%$.²⁴

There are other parameters and variables in steady state which are specific to our model,

²⁴Data for the U.S. on the financing premium is available at <http://research.stlouisfed.org/fred2/>, whereas data on the leverage ratio is available in Rajan and Zingales (1995).

namely:

Loans/Deposits in SS	$\frac{L}{D}$	0.75
Bank Capital Requirement	α_e	0.08
Deposit Insurance Costs Parameter (risk sensitive dep. ins. rate)	δ_e	0.0000045
Preference Parameter	β_0	1

Table 3: Calibration II

$\frac{L}{D}$: In steady state, and according to the model, $L = K - N$, where L represents loans without collateral that are granted to entrepreneurs who buy capital to produce the final good. Therefore, real estate and consumer loans should not be included in L , as well as loans secured by collateral. In other words, L should only comprise commercial and industrial (C&I) loans which are not secured by collateral. The Survey of Terms of Business Lending, published by the Federal Reserve, provides data which allowed us to compute the amount of C&I loans not secured by collateral in percentage of all C&I loans (made by all U.S. commercial banks), in each quarter from 1997:2 to 2004:4:

$$\frac{L_{WithoutCol}^{C\&I}}{L^{C\&I}}.$$

Then, using the (U.S., quarterly) banking data, from 1997:2 to 2004:4, available at the Federal Reserve Bank of St. Louis (see <http://research.stlouisfed.org/fred2/>), on (a) the total loans at all commercial banks and (b) the deposits at all commercial banks, we computed the ratio (a)/(b), from which we could proceed, assuming

$$\frac{L^{Total}}{D^{Total}} = \frac{(a)}{(b)},$$

and

$$\frac{L^{C\&I}}{D^{C\&I}} = \frac{L^{Total}}{D^{Total}} \left(\equiv \frac{(a)}{(b)} \right),$$

where $D^{C\&I}$ denotes the deposits that are used in financing $L_{WithoutCol}^{C\&I}$, *i.e.*, the deposits relevant to our model.

Finally, we assumed that $\frac{L}{D}$ corresponds to the average value of

$$\frac{L_{WithoutCol}^{C\&I}}{D^{C\&I}} = \frac{L_{WithoutCol}^{C\&I}}{L^{C\&I}} \frac{L^{C\&I}}{D^{C\&I}} \simeq 0.75.$$

To calibrate the deposit insurance parameter (δ_e) we followed Berka and Zimmermann (2005)'s

procedure, using data from the Federal Deposit Insurance Corporation (FDIC)²⁵ as of December 2006 and assume that, in steady state, the representative bank of our model is an adequately capitalized bank belonging to the subgroup A, as defined by FDIC for the soundest financial institutions - see http://www.fdic.gov/deposit/insurance/risk/rfps_ovr.html. Therefore, the deposit insurance rate corresponds to 3 cents per \$100 of deposits in annual terms.²⁶ In quarterly terms, this means that

$$\delta_e \frac{D}{S} = 0.000075.$$

Since we are assuming that, in steady state, $\frac{L}{D} = 0.75$, and that $\frac{S}{L}$ is always equal to 0.08 (in the benchmark case),

$$\frac{D}{S} = 16.6(6) \implies \delta_e = 0.0000045.$$

The other parameters and variables in steady state are set in the following way:

1. v , $\frac{R^K}{R^F} = l$, $\frac{QK}{N}$, and Z follow from the computation of $\bar{\omega}$, which, according to the optimal financial contract established between the bank and each entrepreneur in steady state, must satisfy the following condition

$$l(\bar{\omega}) - (1 - \delta) \frac{1}{R^F} = \frac{\alpha}{(1 - \alpha)(1 - \Omega)} \left[\frac{1}{R^F} \frac{1}{LEV(\bar{\omega})} - \gamma l(\bar{\omega})(1 - \Gamma(\bar{\omega})) \right],$$

where $LEV = \frac{QK}{N}$ and $\Gamma(\bar{\omega}) \equiv \int_0^{\bar{\omega}} \omega^j f(\omega) d\omega + \bar{\omega} \int_{\bar{\omega}}^{\infty} f(\omega) d\omega$. Details on $\bar{\omega}$ and v computation are available upon request. See also Gertler *et al.* (2003).

2. $\varepsilon = \frac{1 - \delta}{(1 - \delta) + \alpha \frac{Y}{XK}}$; $\kappa = \frac{(1 - \theta)(1 - \beta\theta)}{\theta}$.
3. The variables and parameters must satisfy the steady state equations derived from the model's FOC and optimization constraints.
4. R represents the quarterly steady state real gross return on government bonds. Taking into account the first Euler equation (14) evaluated in steady state,

$$1 = \beta R^D + \alpha_0 \left(\frac{D}{C} \right)^{-\sigma}$$

²⁵ Available at <http://www.fdic.gov/deposit/insurance/risk/assesrte.html>.

²⁶ Be aware that the rates established by the FDIC changed in 2007.

and the relationship between R and R^D (see equation 11),

$$R = R^D + 2\delta_e \frac{D}{S},$$

we set the parameter α_0 to guarantee $R = 1.01$ in steady state (a value which is assumed by many other business cycle models, including BGG, for the riskless real rate of return, since it guarantees an average riskless interest rate of 4% per year), with $\frac{L}{D} = 0.75$.

Figures

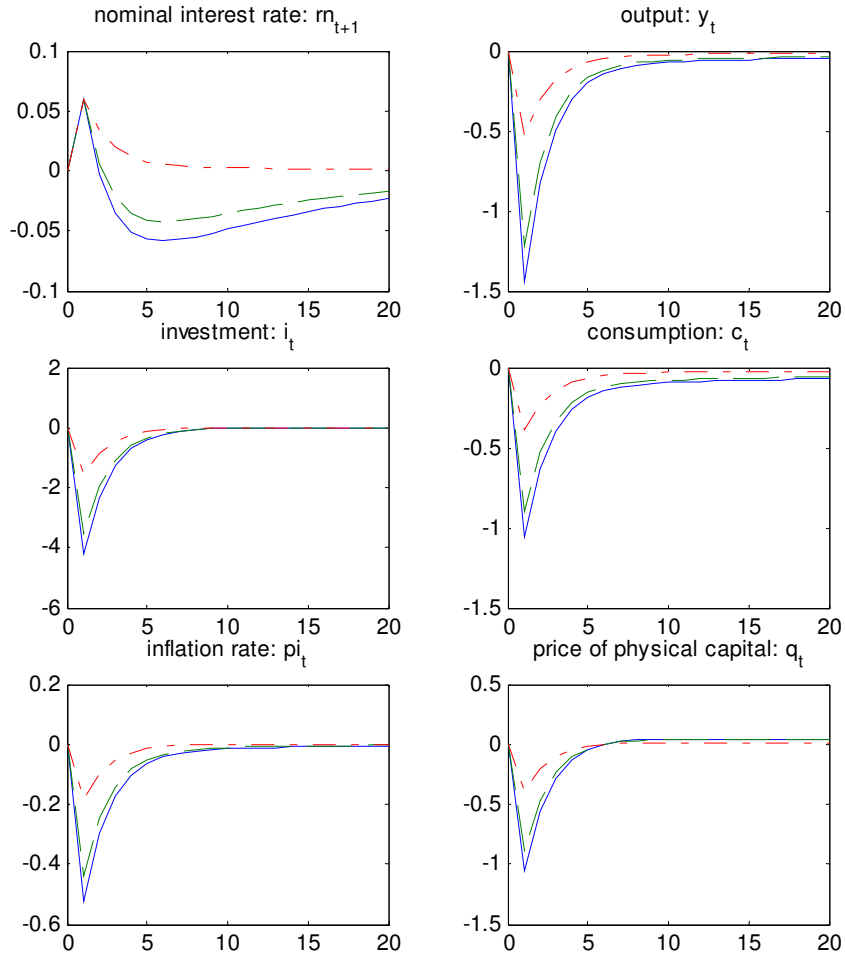


Figure 1: Response of economic activity to a negative monetary policy shock: variant 1 (solid line) - with capital requirements; variant 2 (dashed line) - without capital requirements; variant 3 (dashed-dotted line) - with no capital requirements nor financial accelerator.

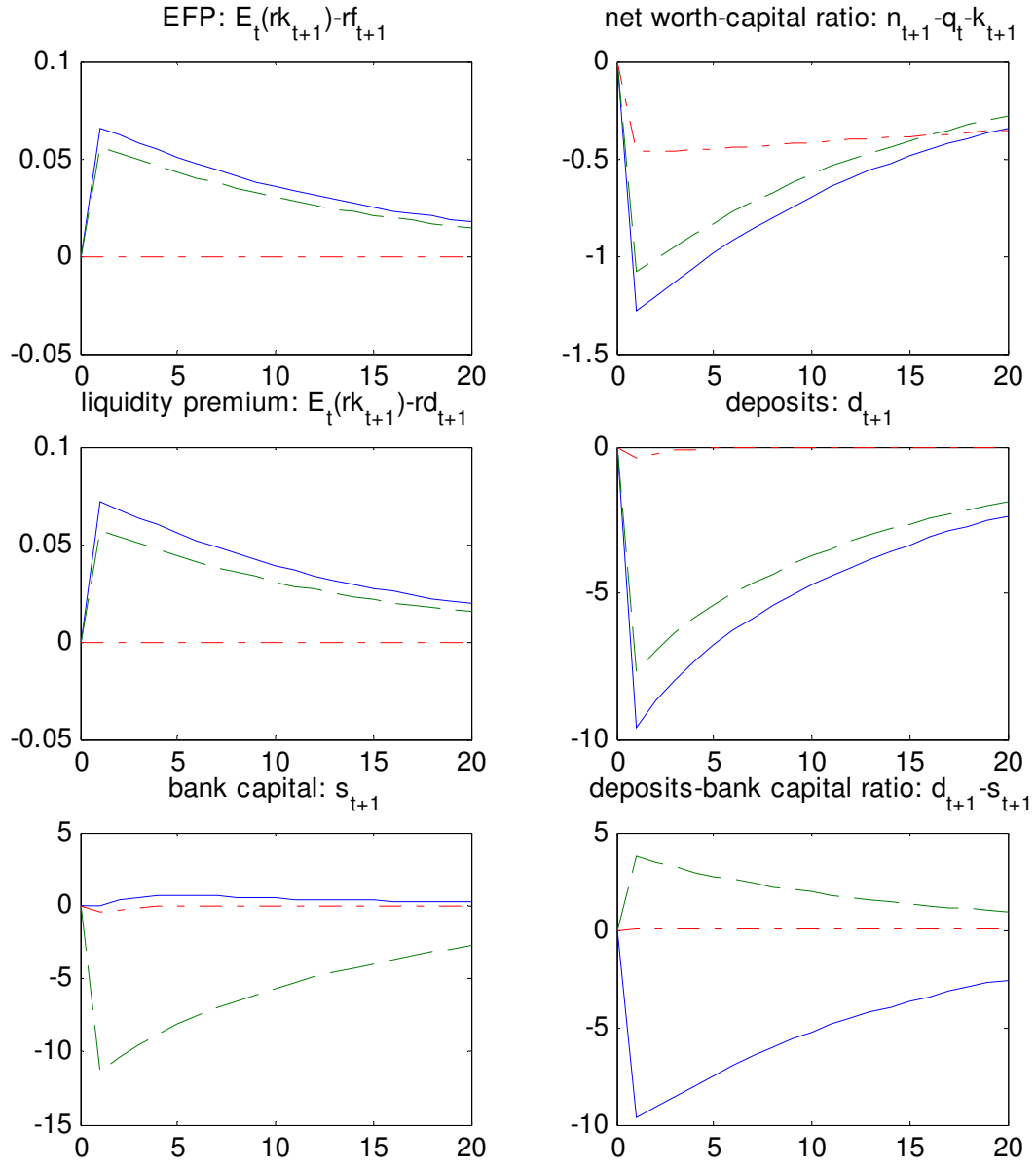


Figure 2: Response of financial variables to a negative monetary policy shock: variant 1 (solid line) - with capital requirements; variant 2 (dashed line) - without capital requirements; variant 3 (dashed-dotted line) - with no capital requirements nor financial accelerator.

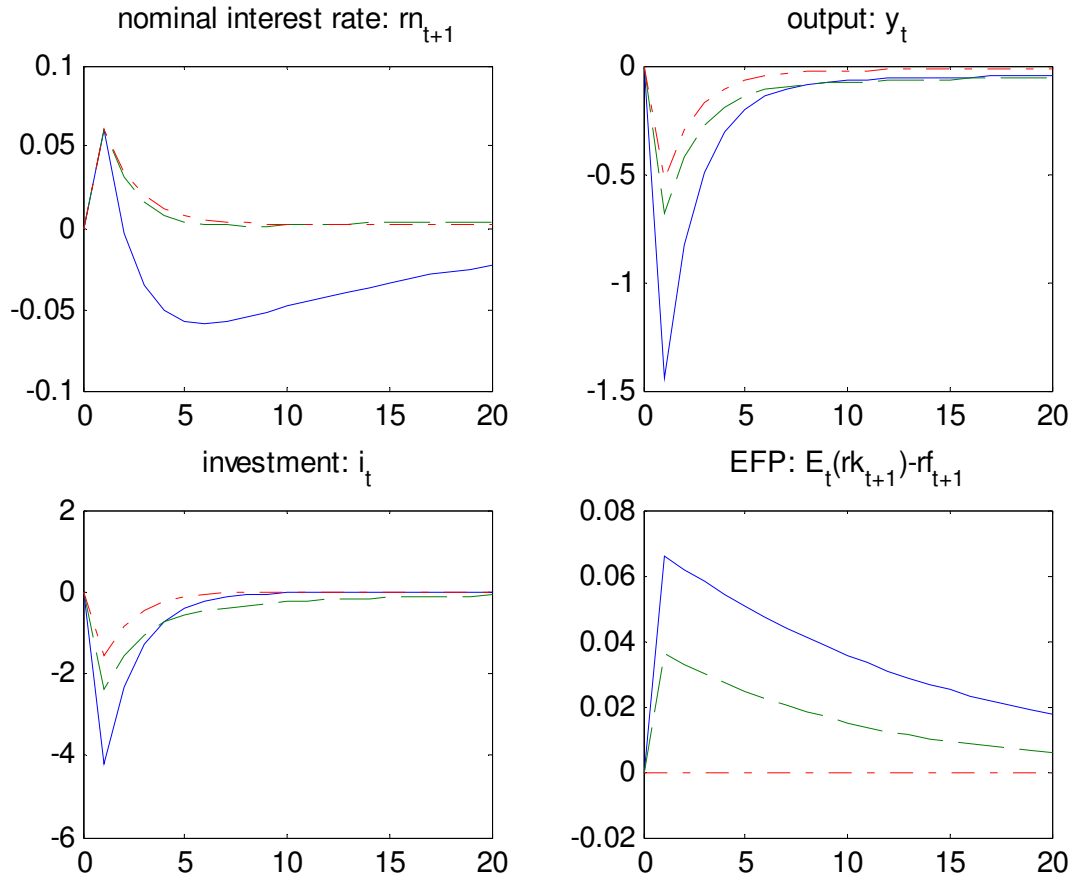


Figure 3: Response of economic activity to a negative monetary policy shock: variant 1 (solid line) - with capital requirements; variant BGG (dashed line) - based on BGG's model; variant 3 (dashed-dotted line) - with no capital requirements nor financial accelerator.

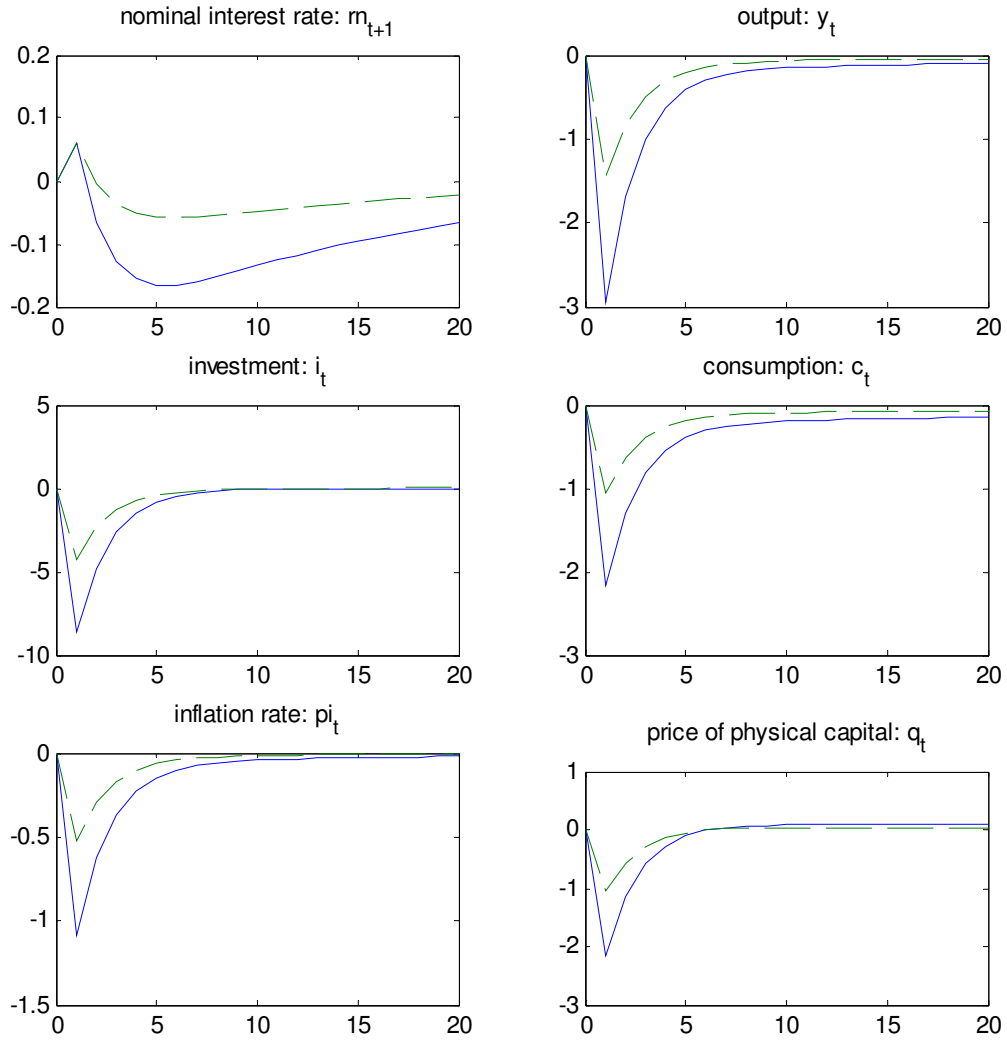


Figure 4: Response of economic activity to a negative monetary policy shock: Basel I - dashed line; Basel II - solid line.

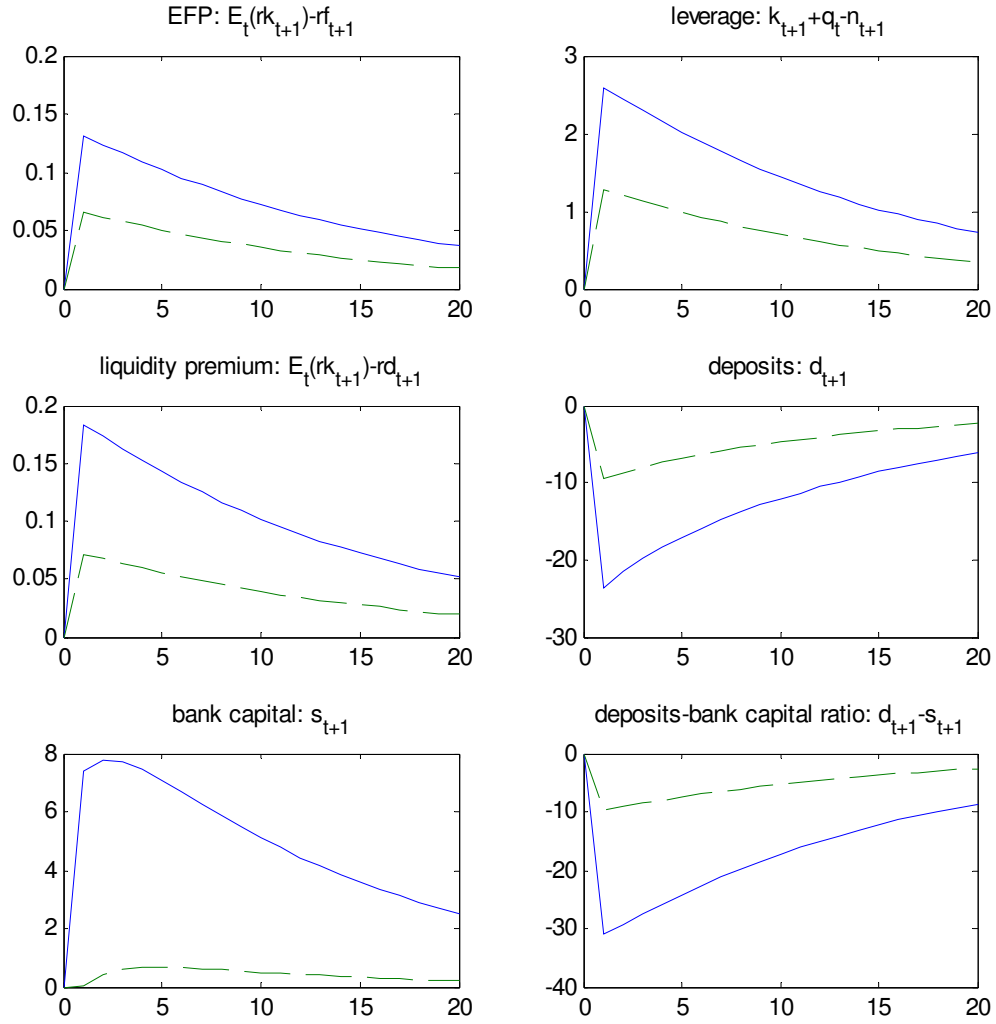


Figure 5: Response of financial variables to a negative monetary policy shock: Basel I - dashed line; Basel II - solid line.

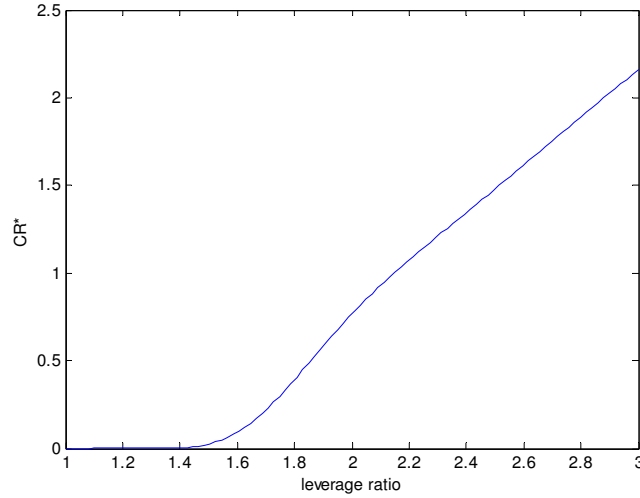


Figure 6: Relationship between the leverage ratio and the capital requirements weights, under Basel II, derived from the steady state optimal financial contract

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